NUCLEAR ENGINEERING VOL. 4 NO. 36 MARCH, 1959

# AEA Senior Staff Changes

THIS time the rumours are founded on fact. Sir John Cockcroft will definitely relinquish his post as AEA member for research, to become the first Master of Churchill College. The new college is to be built in Cambridge and it is hoped that construction will start this year, allowing the first big residential block to be completed by October, 1961. It is intended, however, that some sort of effective education should begin before this date and Sir John is likely to take up his appointment at the beginning of 1960. The date of his leaving the AEA has not yet been decided, but it can be assumed that he will require some period of rest and there is a possibility, therefore, that it will be before the end of this year.

Sir John's going will mean a great loss not only to the AEA itself but to the whole of the nuclear energy industry. His quiet and reasoned counsel has exerted a great influence on developments in this country from the earliest years and the respect that he commands overseas is unparalleled in the United Kingdom. Sir William Penney who will take over the duties of member for research is a man of considerable qualities and, although less well known in the outer world, he can be expected to continue the co-ordination of research and development that has been recently gathering momentum. It is an excellent thing that his drive and energy should be diverted to peaceful applications from the purely military side. It must be remembered nevertheless, that Sir William is already a member of the Authority and no replacement for him has yet been announced nor has a director for the Atomic Weapons Research Establishment yet been found. From the Authority's point of view, therefore, the changeover, while solving one problem, creates a new one. The AEA has seen in the past how difficult it is to replace senior people and, with Sir John and Sir William, they are faced with the problem of finding substitutes for men whose quality and experience are practically unique.

**The Chairman Also**

There are strong grounds for believing that Sir Edwin Plowden will also leave the AEA this year. His original five-year term expired in 1958, and only with difficulty was he constrained to accept a further year in office. It is difficult at this stage to assess the results of his leaving as he never assumed the same positive public rôle as did, for example, Admiral Strauss. Certainly his post is no sinecure and he must take considerable credit for the cohesive front that the AEA presented to the outside world and for the continuity and success of those first strenuous and turbulent years.

**Member for Overseas and Industry**

A more immediate departure is that of Mr. W. Strath, who leaves to become Permanent Secretary to the Ministry of Supply, from April 1. He is to be replaced by Sir Alan Hitchman, at present Permanent Secretary to the Ministry of Agriculture.

The post of member for Overseas and Industry carries heavy responsibilities; its nearest equivalent in a commercial organization, is sales director and, furthermore, sales director of a very large manufacturing organization; with, in addition, considerable public relations and extra-industrial sales commitments abroad. These duties have not been accepted fully in the past and, whereas the controlling privileges of the AEA have been fully exploited, the attendant liabilities have not received the same active attention. It is difficult to understand why, when it has been an accepted principle for so long that senior sales staff should have technical training and preferably a long experience in the business, that Mr. Strath's successor should be selected from a body so remote from atomic energy. Irrespective of personal qualifications, we should have thought that technical experience was essential and, unless it is Government policy to hand over much more of its development and manufacturing business to industry than it has so far indicated, then industry can but feel that it is not receiving the support to which it is entitled. The Government must face up to the fact that the technical competence of the AEA is being progressively depleted and its prestige both here and abroad must inevitably decline.

This will have repercussions throughout the whole nuclear energy industry because, while it retains such a complete fuel monopoly, commercial organizations must needs depend heavily upon the Authority, not only for technical assistance but also for commercial leadership. An unusual position, perhaps, for a Government body, but that is the situation and it calls for other than " usual " political appointments.

# U.S. Programme Report

IN view of the widespread discussion over the supposed findings of the Ad Hoc Committee on Reactor Programmes and Policy set up in October last year, the U.S. AEC has decided to publish the complete report now under study by the Commission. It is not surprising that, although the Committee goes further than previous analyses on a number of questions, there are no fundamental technical surprises. It is a salutary thought that the first listed principal objective of the U.S. civilian nuclear power programme (although in fairness it should be mentioned that the report states that the order is not significant) is to "fortify the position of leadership of the U.S. in the technology of nuclear power for civilian use." Economic targets are competitive power in some U.S. areas within 10 years and in a shorter period in friendly foreign countries, achieved through a comprehensive programme of assistance, and an ultimate objective of low generating costs (in absolute terms).

Once more the necessity for a more exact evaluation of nuclear constants is made clear, particularly in regard to the thorium/uranium-233 cycle where uncertainty in the value of eta casts doubts on the practicality of breeding. Similarly, much remains to be done in the fields of metallurgical experiment, fuel element technology and in the design of components. It is recommended that this research be supported by a budget substantially increased over the 1959 figure (now reflected in the White House 1960 record appropriations request) and that a greater fraction should be dissociated from specific reactor projects.

The findings show that an interpretation which simply implied that the development programme should be narrowed, was misleading; rather is the emphasis shifted from the building of large-scale reactors to smaller experimental systems and basic research. The AEC is recommended to subsidize no more large-scale water reactors although experimental projects, to the extent of probably two in 1959, should be supported to test new ideas. It is suggested that the decision on the construction of an advanced OMRE should be postponed until preliminary evaluation of a $D_2O$-moderated, organic-cooled system is complete. Similarly it is proposed that consideration should be given to holding back work on the Hallam sodium graphite reactor to take advantage of SRE operation. Both the SRE and the Chugach sodium-cooled, $D_2O$-moderated projects, should be actively supported. The Committee believes that a major effort should be expended on gas-cooled systems aimed at 1000°F steam, but feels that immediate construction of a flexible test facility is the right approach, backed up by a comprehensive experimental programme. Again with the exotic systems, the emphasis is on research with a view to selection, rather than on reactor projects; in the small reactor field it is considered that the plants under construction or planned are sufficient for the present.

In effect then, while an increase in expenditure is recommended, the proposal is that the money should be spent on fundamental and applied research leading to relatively small-scale experimental reactors, rather than on the more *ad hoc* approach that has characterized the U.S. construction programme to date. It has yet to be seen how the administration reacts and whether the public-private utility controversy continues to distort opinions.

# AEA Patent Exploitation

The AEA, conscious of the many inventions originating from its research establishments which have an application outside the atomic energy field, has set up a department to exploit this knowledge and, at the same time, ensure that the accumulated experience is not wasted or duplicated. The whole question of whether the AEA should sell or give information, is by no means devoid of controversy, but selling is the principle upon which it works. Of more importance, however, is the loss to the country's engineering skill, should the devices and techniques developed by the AEA fail to receive the attention they deserve or fail to find application in industries where perhaps they are badly needed.

Should the Authority regard the inventions solely as a source of income, then it is likely that its attempts at exploitation would meet with a certain amount of resistance particularly if it tries to strike too hard a bargain. It would appear, however, that it is regarding this in a much more altruistic light and is concerned on the financial side, more with paying for the cost of bringing these patents to the attention of interested parties and, in some cases, protecting those companies who have put in a significant amount of effort in co-operative development, than in filling the coffers of the Treasury.

In addition to its own patents, the Authority also controls those received under agreements with the governments of the U.S.A. and Canada and many of these are available for general use. The Authority proposes to grant licences to suitable manufacturers, in both the United Kingdom and overseas countries; these will normally be non-exclusive but, in exceptional cases, a sole licence may be granted. Terms for the use of a patent are subject to negotiation and the royalties charged will generally be based on the value of the patent and the advantages likely to accrue to a licensee. An important additional service that the Authority is prepared to give, is the provision of sufficient technical know-how to enable the patent to be fully used. Should this involve excessive assistance, then some additional charge would be made, but only rarely would this be heavy.

# DIGEST...

## *Surveying Significant News*

### Heavy Water Moderated Reactor Studies; Steam Cooling Probable

The proposals of the S. African Atomic Energy Board for the construction of a heavy water manufacturing plant with an output of 50 tons per year can be linked with the mounting interest inside the U.K.AEA in heavy water moderation. To provide a second string to the AGR a series of competitive studies has been made by the AEA and it is likely that the announcement of their appraisal will be made shortly. Almost certainly the selected system will be a pressure tube reactor with heavy water moderation and steam cooling. Although gas cooling (presumed carbon dioxide, nitrogen, hydrogen) has been regularly discussed by the AEA it is only recently that steam has been mentioned as the probable coolant. With such a system, near-saturated steam enters the reactor, all the nuclear heat going into superheat. Approximately one-third of the superheated steam is used for driving the turbine, the remaining two-thirds being required to raise saturated steam from the condensate to feed back into the reactor. The heavy water is largely insulated from the coolant circuit and remains relatively cool. The system does offer the prizes of direct turbine drive without heat exchangers, high temperature operation and good neutron economy; at least on paper the system offers better economics than do the light water moderated types.

### U.K.-Euratom Agreement Signed

The U.K.-Euratom co-operation agreement was finally signed in London on February 4 and the full text of the agreement made known. As was expected, apart from eliminating the necessity of individual agreements for the sale of power reactors between member nations and the U.K., the pact does little to foster trade or make any material contribution to co-operative development schemes. Stress was laid on the fact that the terms covering the exchange of information and experience would be fully implemented, but no positive measures were indicated.

The provision of article 8 may have repercussions, however. In this the Authority and the Commission undertake " to provide each other and persons within the Community or in the United Kingdom with assistance in the design, construction and operation of facilities for the manufacture of fuel and for the processing of used fuel." As in a number of other articles, there is also the proviso that this shall be on commercial terms and no indication was given as to what " commercial " means. But this does imply that companies in the U.K. wishing to set up fuel fabrication facilities can demand full information. Article 10, however, contains no similar provision that commercial organizations within the U.K. can acquire fuel as authorized concerns in the Community will be able to do.

### O.E.E.C. Collaboration in HTGC Project

Final agreement was reached in Paris on February 12 on the terms for the combined development of the HTGC project at Winfrith Heath. The project has been given the name " Dragon " and is expected to cost some £13½ milfion over the next five years. Twelve nations will be participating; in addition to the United Kingdom and Euratom countries, Austria, Denmark, Norway, Sweden and Switzerland will be concerned. The U.K. contribution will be approximately £8 million. This is the third major venture of the European Nuclear Energy Agency, the other two being the BHWR at Halden (see page 106) and the Eurochemic process plant under construction at Mol.

### Site for Zeta II Questioned

Although at the Geneva Conference it was announced that thermo-nuclear research would be moved to Winfrith Heath and Mr. D. W. Fry has since been appointed director of the establishment, it is likely that the project will have a new site. Strong representation has been made that Winfrith Heath is too distant from the University centres and Culham airfield (no longer used by the Fleet Air Arm) is believed to be the final choice. Conveniently near Oxford and only a few miles from Harwell it satisfies the main criteria.

## High Temperature Facility at Windscale

To provide physics information for the final design of the AGR core, a new reactor is to be built at Windscale. Named HERO (Hot Experimental Reactor, zerO power) the facility will comprise a 19 ft dia., 19 ft high graphite structure assembled in a steel vessel, with provision for operation at high temperature in an atmosphere of carbon dioxide. The reactor, which is scheduled for completion early in 1961, will be operated by the R & D Branch of the Industrial Group. The core is to be built in such a manner that various lattice parameters can be investigated and, although fuel will initially be uranium oxide canned in beryllium, it can be expected that stainless steel cladding will also be studied. Maximum power of the reactor is a few watts and the operational temperature will be determined by the heat input to the circulating gas from external heaters. Estimated cost of the facility is £1¼ million.

## U.S. Atomic Energy Finance Estimates

President Eisenhower has once again asked Congress for a record appropriation for the Atomic Energy Commission (1960 fiscal year). The total of $2,669,500,000 shows a substantial increase ($215,284,000) over this year's budget. A clearer picture of the way the figure has increased can be gained from looking at the totals for the past few years: 1957, 1,919 million; 1958, 2,299 million; 1959, 2,454 million; and 1960, 2,669½ million. The 1951 figure was only $494,638,000.

## Diffusion Plant Construction Begun in France

Work has started on the French diffusion plant for enriching uranium, at Pierrelatte under the control of the U.S.S.I. (Société pour la Construction de l'Usine de Séparation Isotopique). The Group was formed in December last year and comprises Alsacienne de Constructions Mécaniques, C.S.F., Heurtey, Rateau, Société des Forges et Ateliers du Creusot S.F.A.C. and Ugine, under the presidency of M. Baumgartner.

The original design study was undertaken by S.R.T.I. (Société de Recherche et Travaux Industriels) which comprises C.S.F., Rateau and Ugine, and the Department of Physical Chemistry of the C.E.A. The plant will include aluminium oxide membranes developed by C.S.F. and exhibited at the Scientific Exhibition which supported the Geneva Conference.

## Japan Still Hovers

Japan has not yet signed the contract for a power station as tendered for by three British consortia. One of the reasons given is that, although all similar, the tenders are £1 million above the budgeted £30 million. But as a large proportion of this total will go on local Japanese contracts the argument has its weaknesses. Behind the scenes reports indicate that strong opposition has come from the socialists, who do not want the contract placed with a foreign firm.

## The West German Programme Begins to Gather Momentum

Positive steps have now been taken in West Germany to allow the 500 MW nuclear construction programme to be completed by the scheduled date of 1965. The Bundestag has passed, without opposition, to the committee stage, a Bill which would define the responsibilities of the Federal and the individual Land Governments. Granting of licences, safety standards, and coverage of risks up to £41 million not met by user insurances are envisaged as national obligations. A group of northern utility companies has already placed orders for design studies with Babcock and Wilcox (Germany) for a 100 MW Calder-type reactor and with A.E.G. for a 100 MW water moderated and cooled reactor with superheat. It is understood that two-thirds of the total cost of £1 million will be born by the Government. More recently Siemens were awarded a contract for the design study of a 100 MW gas-cooled heavy water reactor by a group comprised of several utility companies, the Bavarian State and Farbwerke Hoechst. Design of a 15 MW prototype high temperature gas-cooled reactor incorporating uranium-graphite pellets as fuel was completed last spring by Brown, Boveri (Germany) in collaboration with Krupp under contract to AVR Düsseldorf, a group of regional power companies. AVR has been reorganized as a limited company and is expected to sign a construction contract shortly, for a plant to be built alongside the Land Northrhine Westphalia Nuclear Research Centre at Juelich. Early in February Gesellschaft fuer Kernenergie in Schiffbau und Schiffahrt signed an agreement with Interatom (comprising Demag and Atomics International) for an organic-moderated reactor for merchant ship propulsion. The initial contract calls for a 2½-year development period based on a 10,000 s.h.p. unit leading to designs for a larger version. No decision has yet been taken on whether a prototype should be land-based or sea-going.

## Reactor Briefs

GETR the General Electric 30 MW(t) submerged tank-type test reactor diverged at G.E.'s Vallecitos Atomic Laboratory early in February.

# Nuclear Design and Manufacture

An introduction to the specialized design and manufacturing techniques that may be necessary in nuclear engineering projects and some indication of future trends.

BEFORE discussing the special considerations involved in the design and manufacture of equipment destined for nuclear energy applications, it is necessary to emphasize that nuclear engineering is simply another branch of engineering; that is, another facet of the business of designing and making things. There is no mystique associated with atomic energy equipment; on the contrary, entirely new techniques will inevitably be suspect and are likely to find their initial application in branches of the discipline which are less exacting. One of the guiding principles behind the building of Calder Hall, was that the whole construction should be based on known techniques, or with only minor extrapolations into unfamiliar fields. This is not the same as saying there is nothing new or nothing special in nuclear engineering. The demands of this growing industry mean breaking new ground on many fronts, but as a progressive process of development, rather than as a leap into the complete unknown.

As with all specialized branches of engineering, there are certain requirements in nuclear technology which, even if self-evident, are sufficiently important to be worth reiterating.

Without question, atomic energy, if improperly treated, is a dangerous force and a paramount consideration, therefore, in the design of any plant, is that it should be safe; safe from the point of view of the process, the operators

HIGH ACCURACY. Special purpose equipment has been developed by electronic companies for assessing the characteristics of ZETA.

RELIABILITY. For the primary circuit of the Dounreay fast breeder reactor, John Thompson's carried out a 100% X-ray check on all welds.

and the environment. This "safety at all costs" requirement places a high premium on the reliability of the basic design of the whole plant and also on the reliability of individual components. Reliability is not a new concept and there are few industries where breakdowns do not cause trouble and cost money, but with nuclear energy the penalties for mistakes and failures can be heavy. In general, with modern plant, the basic design must be so fundamentally safe, that it is practically impossible for a component failure or even a combination of component failures to cause a catastrophic accident, but even quite a simple failure can cause expensive delays. An example of this is the jamming of the scanner gear on the Windscale reactor No. 2, a relatively minor mechanical failure, which necessitated many weeks of planning, the building of special equipment and finally many hours of repair work in order to correct the fault.

## DESIGN

The designer of even the humblest component, particularly in, say, the primary circuit of a reactor, carries a heavy responsibility and whether the component is the complete reactor vessel or a simple pipe coupling, it is essential that he, at an early stage, has this question of reliability in mind.

### Reliability

A high standard is, of course, demanded in most engineering equipment, but ultimate reliability costs money and in general, purchasers are prepared to tolerate a small failure incidence rate, in order to gain a significantly lower mean cost. Also, short lifetimes for simple and cheap components in plant which can be regularly maintained, without interfering with overall production are probably preferable and more economic than the longer life associated with complex designs. This philosophy may even apply to certain of the ancillary circuits associated with a nuclear reactor, or to some equipment designed for development work only, which itself is of rather short duration. However, where equipment is directly associated with a radioactive circuit, be it in a reactor, processing plant, active fuel cell or the like, long life and durability will take priority over cost and it is the designer's responsibility to produce a machine which will fulfil these requirements and, at the same time be competitive (on price) with similar equipment produced by other manufacturers.

A piece of equipment must, therefore, be designed down to the last nut and bolt. A good overall design can be

METALLURGICAL EXAMINATION.—Creep-testing machines in operation at the research laboratories of the G.E.C. Simon-Carves Atomic Energy Group at Erith, Kent.

ruined by giving only casual attention to minor sub-assemblies.

The special nuclear conditions under which the plant may have to operate, may be fully specified by the purchaser or by a supervisory design body, but this will not always be the case and it is still the responsibility of the designer to make sure that all environmental conditions are appreciated. There has been criticism in the past, that component manufacturers have not been taken into the confidence of plant designers and given such full information. Inevitably, there will be breakdowns in the lines of communication and it is imperative that the type of special problem likely to arise is understood so that the significant questions can be asked.

**Compatibility**

The over-riding conditions imposed by chemical compatibility will, in many instances, be obvious. For a piece of equipment required to work in a given atmosphere, or to handle a given fluid of known chemical composition, materials can be chosen appropriately. It is, nevertheless, as well to remember that traditionally acceptable corrosion rates may not be tolerable and traditional corrosion data may not even be applicable, if, for example, the fluid is in a highly ionized condition or if the complete assembly is mounted in a high radiation field.

Chemical compatibility may not simply be a problem of corrosion, as it affects the component itself. In the primary circuit of a reactor, it is vital to avoid the contamination of the circuit by elements which become highly active in the presence of a neutron flux, or by elements which can, in turn, form corrosion problems in other components. Copper must be eliminated from the primary circuit of the present range of gas-cooled reactors, because of the danger of the particles settling on the fuel elements and penetrating the sheath.

Exposure to radiation may be a serious limitation to the choice of materials that can be used, because of changes in mechanical or electrical properties. Many electrical insulators, for example, quickly embrittle when irradiated leading to insulation failure; glass darkens and graphite grows. On the other hand, some materials are improved such as polythene and, in some respects steel. Detailed data on the particular material which would appear at first sight to be most suitable may, however, not be available as a great deal of work remains to be done in this general field of irradiation damage.

Not only choice of materials will be affected by these considerations. When conventional oils and greases (or even the radiation resistant lubricants now under development) are inapplicable, a complete reassessment of the basic design is probably necessary. Substitution of dry or solid-lubricated or even gas bearings may provide the solution but, it may be preferable to remove the bearings to a position of lower flux, or reorient the whole concept to eliminate moving parts.

Les Exigences de la Fabrication et de la Conception

*Bien qu'en matière d'installations atomiques la conception et la fabrication demandent essentiellement les mêmes procédés que toute autre production, et bien qu'une bonne conception soit basée sur les mêmes critères que dans le cas de la conception pour d'autres applications, les exigences de l'énergie atomique sont plus impérieuses que celles que l'on trouve normalement.*

*La clé de ces exigences spéciales est l'assurance d'un bon fonctionnement. Cela implique non seulement une meilleure conception, peut-être, et seules des techniques de fabrication de première classe, mais demande aussi que l'équipement soit inspecté à tous les stades de sa fabrication et qu'il soit conçu et monté de façon à ce que cette inspection puisse être effectuée. Des problèmes supplémentaires ont trait à l'entretien limité et à distance, la compatibilité nucléaire, la compatibilité chimique, ainsi que les problèmes alliés au fonctionnement dans un flux de rayonnement. En outre, les techniciens de l'énergie atomique vont d'une manière générale de l'avant, et la conception et la production doivent être en mesure de se valoir d'idées et de méthodes nouvelles tout en continuant à conserver la confiance basée sur l'expérience passée.*

Erfordernisse für Fabrikation und Konstruktion.

*Obwohl Konstruktion und Fabrikation für ein Kernkraftwerk im wesentlichen dieselben Verfahren erfordern wie die Produktion anderer Dinge, und ein guter Entwurf denselben Kriterien unterliegt, wie der Entwurf für andere technische Anwendungen, so sind doch die Bedingungen im Gebiet der Kernkrafttechnik strikter als die, die man normalerweise anwendet.*

*Der Schlüssel zu diesen besonderen Erfordernissen ist Zuverlässigkeit. Dies schliesst nicht nur ein, dass vielleicht die Konstruktion besser sein soll, und nur erstklassige Fabrikationstechnik zulässig ist, sondern es muss auch verlangt werden, dass die Apparatur in allen Stadien der Herstellung inspiziert werden, und dass Konstruktion und Montage daraufhin abgestellt sind, dass die Inspektion ausgeführt werden kann. Weitere Probleme betreffen beschränkte Unterhaltungsmöglichkeiten oder solche nur indirekt aus der Entfernung, Verträglichkeit mit der Ausnutzung der Kernkraft, chemische Verträglichkeit und Probleme, die beim Betriebe im Bereich eines Strahlenflusses auftauchen. Weiter ist zu berücksichtigen dass die Technologie der Kernkraft-Energie allgemein fortschreitet, und Konstruktion und Produktion im Stande sein müssen, die Vorteile neuer Ideen und Methoden anzuwenden, und trotzdem das Vertrauen zu bewahren, das auf Erfahrungen, die man bisher gemacht hat, aufgebaut ist.*

Exigencias de Fabricación y de Diseño

*Aunque el diseño y la fabricación para plantas atómicas exigen esencialmente los mismos procedimientos que otras plantas de producción y el buen diseño está basado en los mismos criterios que el diseño para otras aplicaciones, las demandas de energía atómica son más exigentes que los que hay que enfrentar normalmente.*

*La clave de estas exigencias especiales estriba en la seguridad. Esto no solo implica quizás mejor diseño además de técnicas de fabricación de primera categoría, sino que también exige que el equipo sea inspeccionado en todas las etapas de su fabricación y que sea diseñado y montado de modo que esta inspección pueda llevarse a cabo. Los problemas adicionales se relacionan con mantenimiento limitado y a distancia, compatibilidad nuclear, compatabilidad química, y los problemas asociados con funcionamiento en una fluejo de radiación. Además, las tecnologías de energía atómica están avanzando generalmente y el diseñado y la producción han de poder aprovecharse de nuevas ideas y métodos modernos, reteniendo entretanto la confianza basada en la experiencia pasada.*

A further compatibility criterion that can arise, concerns the neutron economy of the system. Materials in a reactor system must be carefully chosen to avoid excessive neutron capture, which would impair the reactivity of the core. In the core itself, limitations imposed by reactivity are likely to be well known, but similar problems can arise in equipment surrounding instrumentation or in apparatus for in-pile work.

**Maintenance**

Limited access to equipment is a characteristic not only confined to that installed within a reactor pressure shell, but is likely to concern all equipment associated with active or shielded material. Two possible solutions are remote maintenance and the elimination of maintenance, almost certainly insured by duplication or even triplication of equipment, with provision for remote changeover. In either case, standard designs are likely to be inapplicable, and a complete re-thinking is required.

**Integrity and Inspection**

Frequently one of the most complex design parameters, is that of circuit integrity. This may be critical because of the value of the material in a circuit, for example, heavy water or because of the dangers associated with a leak, of radioactive or corrosive fluid. Complete integrity demands not just theoretical confidence in the basic design but certainty. This in turn implies that the equipment must be built so that it can be thoroughly inspected. However great the background of experience in manufacturing a product, unless each item can be properly tested prior to installation, then the basic design will be unacceptable for important circuits; this has assumed particular significance in welding, where 100% X-ray is demanded. Inspection must, therefore, be regarded not simply as a production requirement, but as a design requirement. It will also be necessary in some instances to provide facilities for testing even after operation. This may imply simply the periodic removal of a test sample to check irradiation damage, or may extend to complete sequence testing as in the control gear.

**Operational Conditions**

Due consideration must also be given to the manner of operation; some safety devices may not be required to operate more than once or twice in the lifetime of the complete plant. The dangers of seizing in such infrequent operation are self-evident, but it is up to the designer to choose materials and systems that will minimize this possibility.

In spite of all precautions, the results of a failure during operation cannot be ignored. Some forecast must be made of the sequence of events, to ensure that these tend towards a "safe" rather than a dangerous condition. A single failure is likely to lead to a chain of either fault conditions or sudden changes in a number of the plant parameters. Assessment of the most likely chain of events may be difficult and it may even be necessary to build in a calculated weakness to ensure that the reactions move in the right direction.

## MANUFACTURING

Much of what has been said about the design of nuclear equipment applies equally to its manufacture. However good basic design may be, without a standard of manufacture equally geared to special demands, a poor product will result. Basically, of course, this demand is for good engineering practice, although exceptional standards of accuracy will frequently be demanded with tool-room techniques applied to quite massive equipment.

**Inspection**

The most critical phase of the manufacturing process concerns inspection which must be thorough, comprehensive and inexorable at all stages. The producer must also be prepared for extensive customer inspection and although this can involve a great deal of trouble, it is likely that the manufacturer will learn a great deal about his own product and will be able to apply the results of this intensive scrutiny to raising the standard of his normal equipment. He must appreciate, also, that standard methods of non-destructive testing may not be sufficient and the customer is quite likely to demand full operational behaviour testing, on full-scale test rigs before accepting equipment. Companies able and willing to provide comprehensive test facilities will carry a considerable advantage over competitive concerns less well equipped.

In many industries it is possible to do a certain amount of development "on the customer" (i.e., after the equipment is built) and, in fact, this is a recognized method of developing new techniques especially with expensive equipment. It is rarely possible, however, with the more important nuclear engineering plant. Complete systems will be progressively commissioned and will require modification as commissioning data are collected and, although a certain amount of component modification may be possible, the amount of time and effort that can be devoted to it, is likely to be small. Furthermore, in a reactor project once the approach to criticality has been made, it is probably too late to make modifications to the components. Similarly, in active cell work, once active material has been introduced, equipment will be inaccessible.

**Shop Practice**

In addition to a high standard of workmanship, backed up by exhaustive inspection, it is probable that the manufacturing conditions themselves may have to be carefully watched. In a number of processes clean conditions must be established from the outset and what for other industries would be normal shop practice can turn into a near-laboratory operation. It is likely, also, that much more needs to be known about the background of the constructional materials than is usually the case and production flow sheets must be produced which will allow a complete back-check on materials.

It is perhaps unnecessary to emphasize the necessity for following the designer's specifications both as regards details and materials. Modifications on the shop floor, which in conventional engineering may be normal practice, can have fatal consequences unless full liaison between the designer and manufacturer is maintained.

REMOTE HANDLING. Radioactive materials require specialized handling facilities to ensure protection for personnel handling them.

## FUTURE TRENDS

It is possible that as time goes on, specifications for materials and methods of manufacturing may be relaxed, but safety must come before all, and only after a long record of reliable operation can specifications be reconsidered. There is a strong tendency to accuse safety authorities of being over-cautious, but frequently this attitude arises from a lack of appreciation of the consequences of a mistake or of the imperfections that have been tolerated in the past. Manufacturers can be overconfident that previous techniques are good enough and are equally applicable to the new conditions or the new materials.

Taken over all, it is more probable that greater integrity will be demanded rather than less and that higher standards will be applied to more and more conventional equipment. Certainly there is plenty of room for development in the design and manufacture of quite standard items which need to be investigated from a fundamental standpoint rather than from one of present expediency. An example of this is in foundry work, where the elimination of porosity in castings presents a considerable challenge with valuable rewards for its successful solution.

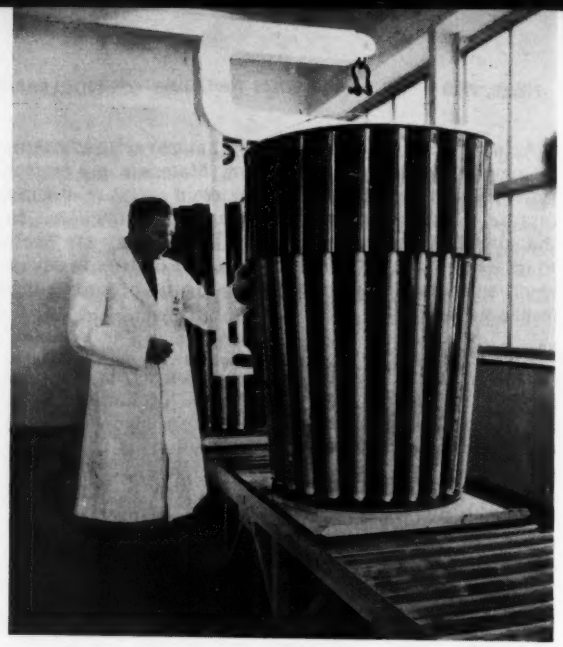
New materials are also likely to assume importance in the nuclear engineering field. Although we have not at present an extensive water-reactor programme, it is likely that zirconium will become an important material and later perhaps vanadium and niobium. Production of these at an economic rate and their manipulation are matters of major consequence. Beryllium is a metal which requires not only the establishment of techniques for fabrication but a completely new design approach which exploits its advantages and acknowledges its limitations. The technology of graphite is again by no means complete and this material is likely to assume importance not merely as a "filler" material but also as a structural material.

The field of development is not confined to the special metals. New alloys both ferrous and non-ferrous will be required by engineers and physicists, such as steels with progressively lower cobalt content.

Certain general technologies are also likely to grow at a rapid rate. The whole field of remote handling is at present in its infancy, but once the generating authority's nuclear power stations come into operation, the demands for such equipment will be considerable, particularly for the inspection of irradiated fuel elements. Should pyrometallurgical techniques prove to be desirable, processing and remote fabrication of fuel elements are likely to be much graver problems than they are now, even taking into account the familiar complexities associated with plutonium handling.

Whilst companies anxious to invest a significant fraction of their effort in the nuclear engineering field must be prepared to do a great deal of one-off work, there is, nevertheless, room for standardization of equipment. This applies not only to major items of equipment such as fuel elements, but also to the more humble devices such as effluent disposal containers, source coffins, and castles, monitoring equipment, etc.

In the electronics field the drive will be for higher accuracies, greater reliability, faster revolution times and, while quality in design and manufacture are of prime importance, instrument costs cannot be ignored and competition in this field will increase rather than decrease. In many instances equipment can be simplified and yet provide all the facilities that are required by the average user, with consequent saving in materials and production costs. Rigorous fault analysis fed back into the design process can do much to improve reliability without increasing prices.



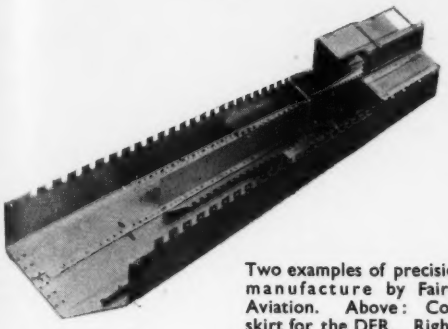
**CLEAN ROOM. Completely dust free conditions are essential on many occasions. Here fuel elements are being prepared for loading into a Calder reactor.**

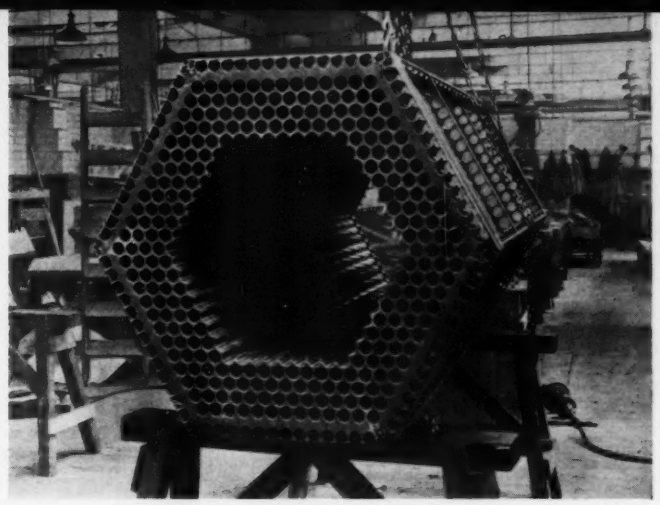
For the many and varied specialized demands the development field is almost unbounded. The major problem is the limited immediate market for such instruments, but the temptation to British manufacturers to base their new designs on recent U.S. developments must be resisted. This is a dangerous policy and, unless we are prepared to leap-frog in our development, we shall be forced to forfeit the leading position that we held, say, three years ago. If, in a particular company, even a small staff is set to trying to devise the ultimate in performance of any particular instrument, the investment is likely to pay handsome dividends, even if the ultimate is never reached.

Although thermonuclear research is not likely to impose very great demands on the outside manufacturer and designer for some time to come, it is worth while bearing in mind the type of equipment that is likely to assume importance. There is little doubt that, as research continues, the demand for high current switching gear will increase, with the additional requirement for higher and higher speeds. Similarly the demand for energy storage will also increase, either in terms of greater capacities with the possible development of an electrolytic type or homopolar generators and allied electro-mechanical devices. Another area of development will be that of large vacuum systems particularly in relation to demountable equipment and seals.

But common to all the disciplines in fission and fusion work, the pressing demand is for new and better test equipment. In the fusion field, RF diagnostic methods are likely to assume even greater importance and very high speed oscillographs will be needed. In the mechanical engineering field, there is still great scope for the extension of existing techniques, particularly ultrasonic and the introduction of new and better methods of flaw and leak testing. The ultimate has not been achieved either in the measurement or even in the specification of many properties.

In many ways, the demands of nuclear engineering demonstrate the general trend of all engineering, but to repeat the point made at the beginning of this article, few industries offer the same rewards for successful design, development and manufacture, yet at the same time, carry the same penalties for mistakes.





Two examples of precision manufacture by Fairey Aviation. Above: Core skirt for the DFR. Right: Gagging skirt in 18/8/1 s.s.

# Industrial Changeover

**British aircraft manufacturers are making an increasing contribution to nuclear design and manufacture. The aircraft industry has ample productive capacity for future large-scale nuclear projects. In this first article a survey is made of the scale of activities of three established aircraft concerns.**

IT is highly appropriate that an article discussing the special requirements of nuclear manufacture should be followed by one describing the nuclear activities of the major British aircraft companies. Aircraft engineering and nuclear engineering are, in fact, closely allied. Both are primarily concerned with problems such as physics, mass flow and metallurgy; both demand a high proportion of design staff to production personnel; both call for intensive research and development, the precision manufacture of large assemblies, careful inspection at all stages of production and the utmost flexibility so that modifications can be incorporated at any stage.

It is obvious from this brief summary that the aircraft industry has much to offer nuclear engineering. Already many of the larger aircraft companies have announced plans for industrial diversification to offset any redundancy likely to arise from the curtailment of orders for military aircraft. It is pertinent then, at this stage, to consider the nuclear work that is now being handled by the aircraft industry and, at the same time, to explore its capacity for future contracts.

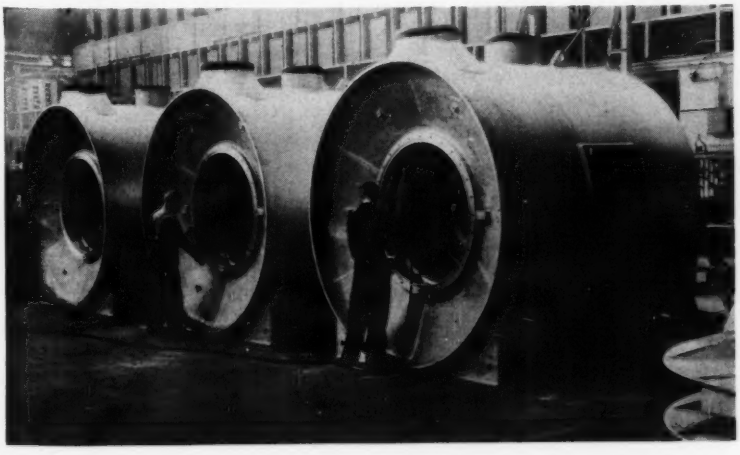
## Fairey Aviation

FAIREY AVIATION was one of the first British aircraft companies to become interested in nuclear contract work. Among the company's more important activities in this respect has been the production of Calder-type fuel element cans. Originally the finning of these cans was produced by machining from the solid; subsequently the company has pioneered a rolling process and special-purpose machinery has been installed to cater for the increasing demand for cans.

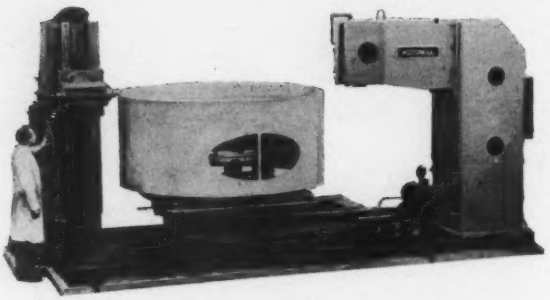
At Fairey's Heaton Chapel (Stockport) works there are excellent facilities for the production of large fabrications in materials ranging from aluminium alloy to stainless steel. During the past 10 years the company has supplied a large quantity of special fabrications to the AEA.

An accompanying illustration shows three of the large devices built at Heaton Chapel under an AEA contract. These units, designated S.250, each comprise a large aluminium shell consisting of six major fabrications. Material for them is obtained from both Northern Aluminium and the British Aluminium Co.

Two departments at Stockport are concerned with the production of these devices: the machine tool division is responsible for welding, machining and assembling, while the press shop deals with the routing of forms, forming and rolling. The S.250s have large domed ends, which are formed in six petal-sections. They are first routed and formed on a hydraulic press and subsequently welded together after tacking in a jig. These end-pieces have a central core, joined to the rest of the fabrication by web-like side-frames. Another part of the device is a motor mounting, a



Three large aluminium fabrications made for the AEA by Fairey Aviation. Each weighs 4½ tons.



For machining large aluminium components Fairey Aviation have developed the Rotomill.

fabrication of some 18 to 19 cwt., which requires, apart from the segmented plate work, the rolling, welding, and hydraulic forming of conical rings and the forming and welding of very heavy-section bars. The whole welded assembly was specially developed to replace and improve on the casting technique originally envisaged for this job.

Individual fabrications are welded into cylindrical housings resulting in a boiler-like structure some 10 ft high and 12 ft long. The total weight is just over 4½ tons.

Another part of the S.250, a four-piece outlet, is produced on a rubber bolster press. The 4,000-ton bolster press has as its most important feature a 21-in. thick rubber blanket, which permits the forming of parts up to 10 in. thick.

Clean conditions must be maintained in the workshop and floor area. No impurities can be allowed to penetrate into the job during fabrication, and after a certain stage, therefore, the housing is screened-off in plastic booths.

Considerable research and development work has been carried out by Faireys on the welding of aluminium structures. Both the argon arc and Argonaut techniques are employed. Using the latter process, 5-in. welds are now made as routine.

With the Argonaut technique (used extensively in the production of the S.250), the weld material (N 6 wire alloy) is fed through a gun automatically from a store positioned above the operator. Three wire thicknesses are used, 3/64 in., 1/16 in. and 3/32 in., and these are fed at a rate of some 230 in./minute. The welding guns are water-cooled, as are the cables of the welding unit. Electric power for the motor feeding this material supply through the gun is provided from a separate power unit—the output being 250 A for 1/16 in. diameter wire and 350 A for 3/32 in. wire.

Argon, which is stored in the liquid phase in a central tank, is supplied through tubes to all of the Argonaut welding guns about the shop; its purpose, as is generally known of this technique, being to prevent oxidation of the weld when it is made. The argon is vaporized on leaving the tank and fed to the gun as a gas. A pressure of 40 lb from the tank permits a supply which enables welders to work at the rate of 45 cu. ft/hr.

Because of the size of the parts under fabrication at Heaton Chapel, various manipulators, rotators, plate rolls and the like are required to handle the work for welding and for assembly. Many of these form part of the stock of equipment at the works, and this equipment also includes facilities for lifting up to 30 tons weight. There is also a large stress-relieving furnace.

For routing, radial arm machines are used with 5 h.p. heads, for work on plates of 1⅜ in. thickness. For special purposes involving repetitive work, equipment such as the Rotomill has been developed. This machine has two high-speed cutting heads for removing stock at a rapid rate when machining large aluminium components.

In addition to aluminium and aluminium-alloy structures, Fairey's also fabricate in steel and stainless steel. Units supplied to the AEA have included structures of up to 80 ft long; some of them were precision-made, for example, the core of the Dounreay reactor, which was built literally to tool-room tolerances.

Extensive work in steel is still under way, and the company holds contracts for stainless steel work for one of the civil atomic groups.

From the foregoing it would appear that Fairey Aviation is extremely well equipped to handle heavy duty fabrications in different materials. The company has a great deal of experience of the manufacture of fuel element cans, machining graphite and developing special purpose equipment such as burst slug detection gear. Fairey Aviation is, of course, a member of the Atomic Power Construction group and the company has already expressed its intention of supplying reactor components, fuel handling gear and special control equipment for any station built by the group.

## Vickers-Armstrongs (Aircraft)

ALTHOUGH comparative newcomers to the nuclear industry, the South Marston (Swindon) works of Vickers-Armstrongs (Aircraft) have made exceptional progress in diverting part of their extensive resources from aircraft production to nuclear engineering. During 1958 the company formed a nuclear design team with a strength of about 100 personnel. By offering good service—the works are not far from A.E.R.E., Harwell, or A.W.R.E. Aldermaston—and by applying their wide range of experience to particularly difficult problems the team has already achieved a high reputation. The design section is backed by a nuclear development laboratory together with excellent manufacturing facilities. Three sub-critical assemblies are now in course of construction. The first of these, EUREKA, has already been installed at Harwell.

### Sub-critical Assemblies

EUREKA has been designed to permit investigation of the effects of varying fuel-rod assemblies which are placed in a tank of demineralized water, having a temperature range of from 0°C to 80°C, the volume of which can be varied as required.

The pile, although designed not to diverge, is remotely controlled, and the associated electronic equipment incorporates all necessary safety interlock devices. The grid structure has been designed to permit the arrangement of fuel rods in varying numbers and patterns. A neutron source in a lead-shielded container is housed in the tank. A removable lead-filled shutter permits the source to be fed towards the fuel-rod assembly and $BF_3$ proportional counters measure the neutron flux.

Heating and refrigeration equipment are installed in the main tank and an agitator ensures efficient mixing. Specially designed dump valves enable the main tank to be emptied rapidly in cases of emergency; two of the three valves are solenoid operated, and are linked to the controlling equipment. A dump tank is provided. A motor-driven cadmium rod is raised or lowered between the fuel elements for fine control of activity. Two larger section cadmium rods are poised over the pile for insertion in case of accidental divergence.

Of the other two facilities one has been designed for graphite-moderated exponential experiments conducted

with advanced fuels. Neutron counts will be plotted at temperatures between ambient and 400°C. The graphite stack is variable in frontal area from 5 ft square to 12 ft square; the depth along the fuel rods can be varied between 7 ft and 9 ft. 4 in.

Radiant electrical heating is employed on the side faces only, leaving the front and rear faces free for rod movements and coolant flow. Pile cooling is achieved by a closed circuit air or inert gas system which enters the working face and leaves at the rear face of the pile. The pile stands in an insulated primary chamber and all operations at elevated temperatures are conducted through a sealed door mechanism.

The pile chamber occupies one end of the containment vessel, the other end forming the personnel chamber. The sealed door between the two compartments has two operating features. The main door is hinged in the normal manner which provides access for erection of new lattice configurations. The swinging door mounts a second circular door provided with an access slide. Rotation of the door and movement of the slide allow the operator to insert a flux detection rod into any of the measuring holes in the pile. Pressure differentials are maintained so that leakage can only occur away from the experimental area into the pile chamber.

The uniform thermal neutron fluxes are supplied by four radium-beryllium sources distributed in a graphite plinth under the pile. A suitable source flask is used for transport and storage of all the sources simultaneously. Fixed and mobile thermocouples are provided for installation in the graphite assembly and preheat oven, for equipment inserted into the pile. The heating cycle, which takes a maximum time of 48 hours, is controlled automatically and recorded. Top temperature trips avoid overheating.

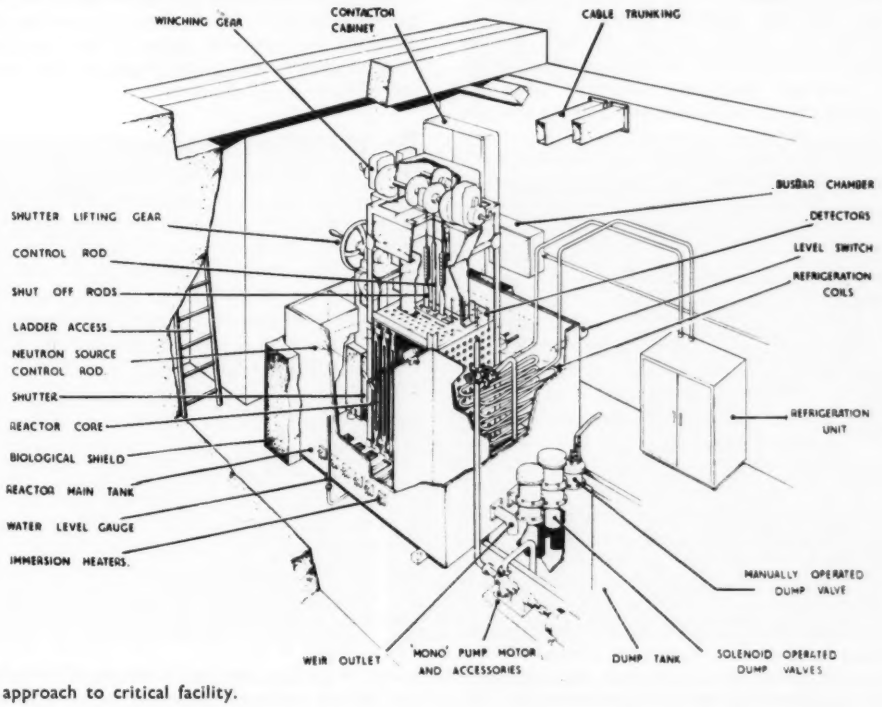
Continuous running alpha monitors are incorporated and all ducts to atmosphere are guarded with glasspaper alpha filters. Fire precaution equipment is installed to handle outbreaks in either chamber. All controls and instrumentation are grouped on a single console mounted on top of the containment. The control operator communicates with the personnel chamber by means of a two-way loudspeaker intercommunication system.

The third facility in course of design is a fine structure experiment which provides primarily for the study of intracell neutron distributions in lattices containing various fuels. Experiments will be conducted both cold and with the fuel and moderator uniformly heated to any temperature up to 400°C. The graphite for the heated assembly consists of machined blocks forming a rectangular stack of maximum dimensions 6 ft by 6 ft by 4 ft 8 in., the last dimension being the length in the direction of the fuel channels.

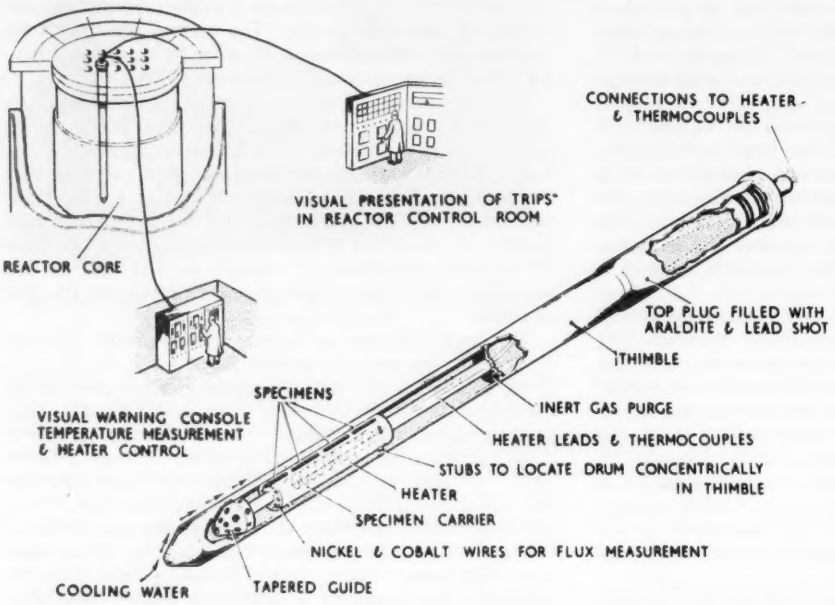
The stack is heated by radiation from electric fire bars situated on the top and bottom faces. It is cooled by a closed circuit air or inert gas system entering and leaving the pile chamber on the same faces as the heaters. The stack is enclosed in a primary containment and access to a central block of graphite is obtained through a sealed door. A large area antimony-beryllium source provides the necessary uniform flux of thermal neutrons. The beryllium tubes are housed in a fixed plinth on one face of the stack, radioactive antimony being inserted when radiation is required. Owing to the intense gamma radiation produced, the antimony is held in a source flask while operators are working on the pile, and is inserted mechanically from an external control console.

The pile chamber is installed inside a second containment, known as the personnel chamber, which also houses a preheat oven and a cooling box. Flux measurements are made by measuring the activity of foils embedded in a central block of graphite inserted in the pile, and it is necessary to cool this block within a half-hour of completion of an experimental period. The cooling box operates with the same cooling circuit as the pile chamber; the full flow being diverted for this purpose.

The personnel and pile chambers are kept below ambient




EUREKA approach to critical facility.


CONNECTIONS TO HEATER & THERMOCOUPLES
VISUAL PRESENTATION OF TRIPS IN REACTOR CONTROL ROOM
REACTOR CORE
TOP PLUG FILLED WITH ARALDITE & LEAD SHOT
THIMBLE
SPECIMENS
VISUAL WARNING CONSOLE TEMPERATURE MEASUREMENT & HEATER CONTROL
INERT GAS PURGE
HEATER LEADS & THERMOCOUPLES
STUBS TO LOCATE DRUM CONCENTRICALLY IN THIMBLE
HEATER
SPECIMEN CARRIER
NICKEL & COBALT WIRES FOR FLUX MEASUREMENT
COOLING WATER
TAPERED GUIDE

Typical materials irradiation rig.

pressure, the pile chamber pressure being the lower of the two. Any leaks that may occur must, therefore, be inwards and away from the operators. The outside of the personnel chamber is shielded with concrete blocks to absorb the radiation produced when the pile is active. Owing to gamma activity, several safety circuits are incorporated to ensure that the source cannot become exposed while personnel are within the shield area.

Vickers are proposing, in the near future, to produce reactors for research and training purposes. A 5MW heavy-water moderated design has already been prepared, and the company proposes to develop pool and tank-type light-water moderated reactors using enriched uranium.

On the design side, the company recently secured an important contract for work on the 7 BeV proton synchroton under construction for N.I.R.N.S. The design of the vacuum envelope, inner liner and drift tubes has been handled jointly by A.E.R.E. Harwell and the aircraft company's nuclear division.

Apart from the sub-critical assemblies and the work on the proton-synchroton, however, the South Marston organization has also been concerned with the design and construction of several loops and rigs in close collaboration with A.E.R.E.

An accompanying illustration shows a typical rig for subjecting materials to very high irradiation. Similar rigs have been supplied for operation in DIDO and PLUTO at Harwell and will shortly be operating in DMTR at Dounreay. The rig illustrated provides specifically for uniform heating by containing the specimens in a drum manufactured in a high thermal conductivity material, so that temperature variations do not exceed 10°C. The rig is cooled by the reactor heavy water flow along the outer surface of the thimble.

The amount of heat which may escape from the rig to the cooling water is controlled by conduction across a gas gap of selected size. This gas gap is calculated so that under all reactor conditions the specimens are overcooled; they may then be brought up to temperature by an electric heater which is "locked on" to the desired temperature either by a closed loop or an intermittent controller.

Nickel and cobalt wires are inserted in the specimen carrier for the measurement of the flux to which the specimens have been exposed. Thermocouples in the specimen carrier control the heaters, provide a visual temperature record on paper and operate warning lights and reactor safety trips. This type of rig requires manufacture to fine limits as the loss of heat from the specimen carrier is entirely controlled by the dimension of the gas gap, which is limited to .0005 in.

A rig of the above-mentioned type is now on proof trial, out of pile, concerned with the heating of beryllia, to temperatures of above 1,000°C; this rig requires most stringent testing, as overloading the reactor primary cooling system would have serious results.

The study of complex loops prior to design and construction frequently involves the use of an electrical analogue for part of the circuit. The physics laboratory at South Marston has a recording and exchange console which communicates directly with the analogue computers in the mathematical services section. The retransmitted parameters are recorded by mirror galvanometers on up to 25 channels, and by cathode ray tube display. The return signals may also be fed back to the loop to complete the circuit to simulate the effect of transient conditions.

Other equipment in course of design at South Marston includes a top-dome viewing periscope for power reactors, a range of vacuum pumping systems, an active material casting unit, glove boxes, flasks for transporting active fuel elements, and physical apparatus such as Cerenkov detection chambers, ionization chambers and developments of the Wilson cloud chamber.

## De Havilland Engine

THE de Havilland Engine Company began to take a serious interest in nuclear matters in 1954, when some of the company's staff were attached to A.E.R.E., Harwell, to examine the possibility of utilizing nuclear energy for aircraft propulsion. The de Havilland team's studies indicated that whilst formidable technical problems would have to be overcome practical solutions might be forthcoming if sufficient research effort were made available.

A more significant result of the work on small highly-rated systems was the realization that small power reactors could be made competitive with conventional prime movers at power outputs as low as 10 MW. With this object in view, the company is closely following the HTGCR programme initiated by the AEA.

In the meantime de Havillands have expressed a desire to undertake any experimental work that will advance the U.K. power reactor programme. In 1957 the company was awarded an AEA contract to design and construct the first high temperature gas loop for testing a new ceramic fuel element in PLUTO. This project involves the simulation of nuclear heating by means of electric elements and the reactor geometry is being reproduced on a full-scale

basis to check that the equipment functions correctly before it is placed in the reactor. Preliminary development work on loop components is also being carried out with the object of proving special features prior to installation in the final assembly.

Particular attention is being paid to the primary circuit as it could become contaminated with radioactive products escaping from the fuel element. Extremely sensitive leak detection equipment is being used to ensure that the specified values are not exceeded.

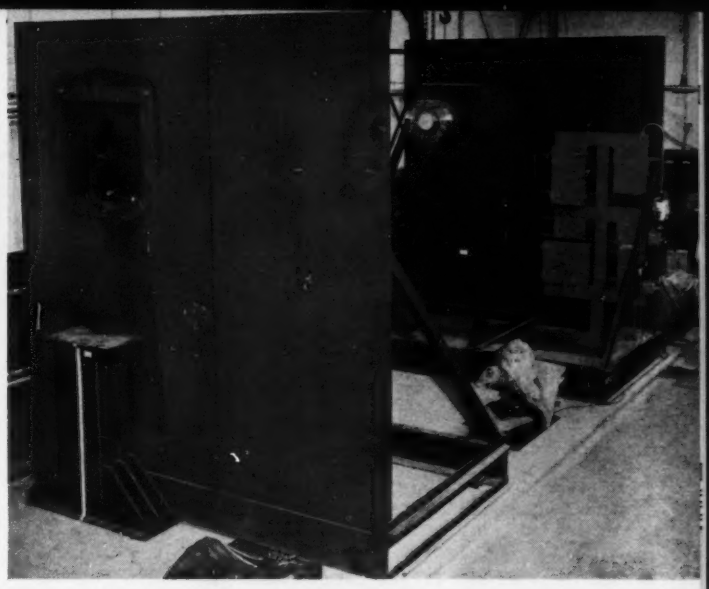
An appreciation of the need for specialized components has led the company to develop certain items as standard commercial products. Typical of these are small high speed gas circulators incorporating self-acting gas bearings. A series of tests are in hand to determine the behaviour of these bearings under simulated operating conditions and to provide data on the most suitable materials for their construction.

A variety of small valves is also being developed for radioactive gas circuits. External leakage is minimized by extensive use of welded or brazed joints. These valves are also being rig tested to ensure complete reliability under operating conditions.

Like both of the aircraft companies previously mentioned, de Havillands have excellent facilities for nuclear subcontract work. Their technical and drawing office sections at the London design office comprise a balanced team with specialist knowledge in most branches of engineering and applied physics. Many personnel have attended the reactor course at Harwell; others have been trained in particular aspects of nuclear engineering.

The company's extensive manufacturing facilities include a factory at Edgware for the production of prototype aero-engines. This factory thus has excellent facilities for " one-off " production and a part of the premises has already been set aside as a nuclear laboratory and assembly room. At Leavesden, where the company's production division is located, there is ample room for the erection and preliminary testing of experimental loops or full-scale nuclear plant.

A short distance away, at Hatfield, is the Halford gas dynamics laboratory, which, although intended for testing gas turbines, could be used to advantage in an examination of mass flow in a large-diameter circuit under varying temperature conditions.

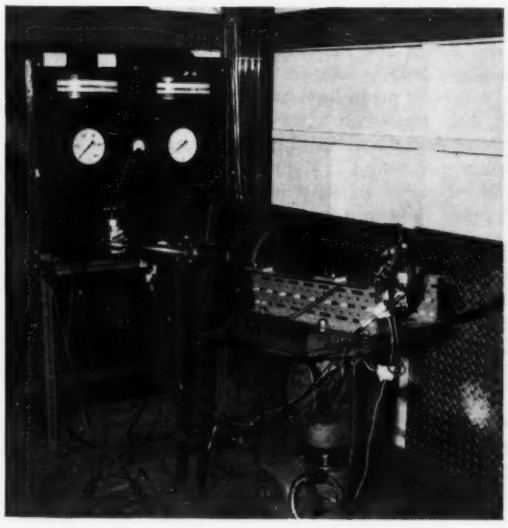


Early stage of erection of PLUTO reactor geometry for simulating heating tests on loop equipment (de Havilland).

Apart from these facilities, the de Havilland Engine Company has a number of divisions concerned with the development of hydraulic and electro-mechanical systems, the investigation of transient phenomena, and many other aspects of fundamental research. In this connection it is worth noting that the electronic computing equipment includes a Ferranti Pegasus high-speed digital machine and a Short and Harland analogue unit.

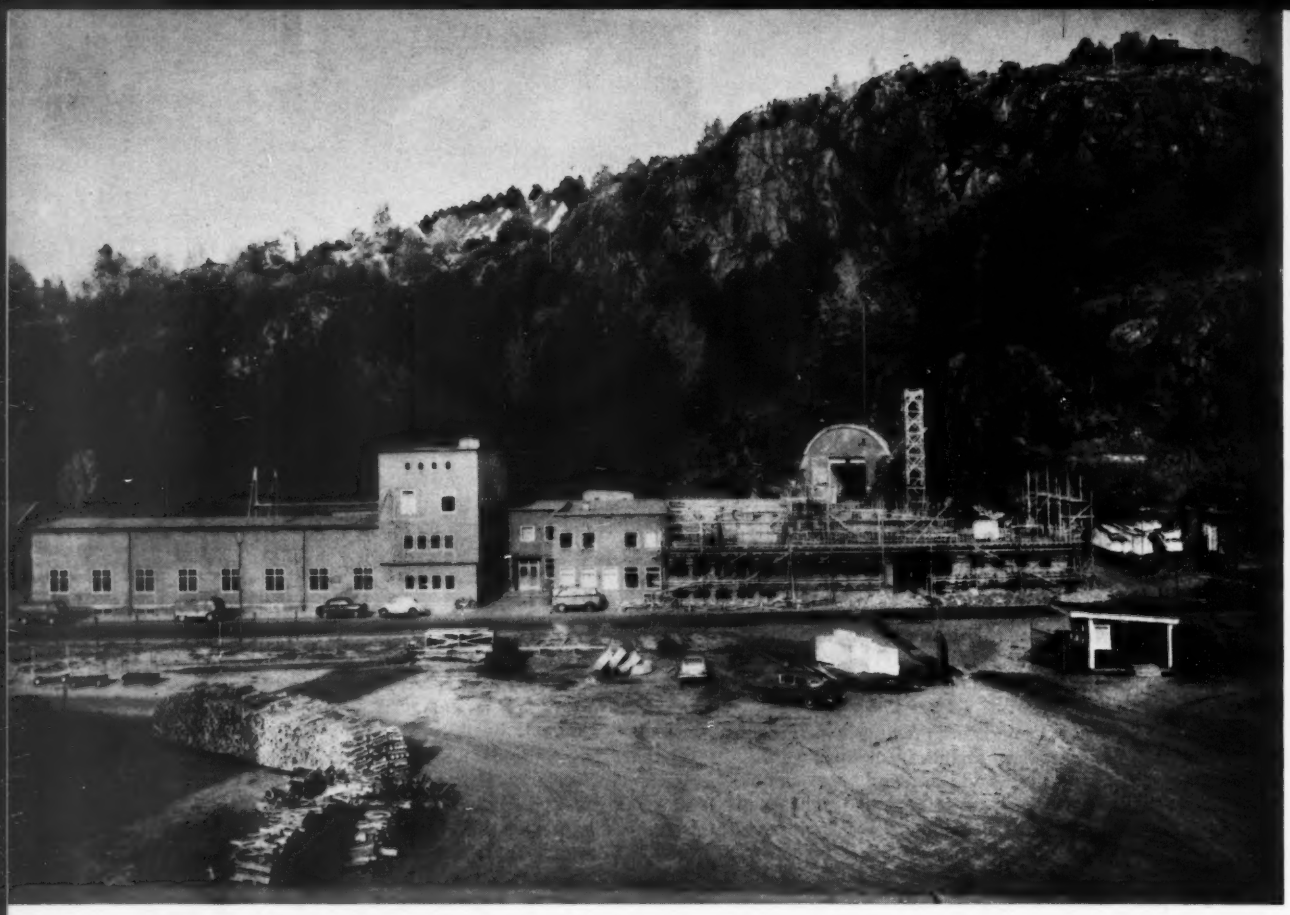
Fusion welding by the inert arc, metallic arc and oxy-acetylene processes is in widespread use; mechanized fusion welding equipment is also available.

For non-destructive tests, the company makes use of all the conventional methods including dye penetrants, fluorescent penetrants, magna-flux and electro-flux facilities for surface examination and ultrasonic and radiographic equipment for internal examination. The radiography equipment, which includes mobile units, covers a range from 60 to 300 kVA.



De Havilland rig for testing the company's self-acting gas bearing circulators

Optical pyrometer temperature check on dummy fuel element during heating experiment (de Havilland).



# Halden BHWR

**The Boiling Heavy Water Reactor at Halden which is scheduled to go critical shortly, has been designed by Jener and built by the Norwegian Institutt for Atomenergi, Kjeller, in close co-operation with industry.**

THE Boiling Heavy Water Reactor at Halden is the only one of its type in the world. Although essentially a Norwegian/Dutch project, participation in the operational programme by O.E.E.C. has given it an international character.

To prevent any possible misunderstanding it should be made quite clear that this project should be regarded—and is so by those responsible—as a large-scale experiment to explore the possibilities of the boiling heavy water concept, and not as an industrial power plant, although a load exists for the steam when the experimental work is complete. This, however, is not likely to be for some time, since the experimental programme is a very heavy one. Furthermore, production of significant quantities of steam is not expected with the first core, which is regarded as purely experimental.

### Outline of Scheme

The Halden reactor has several interesting features, of which the two main ones are the employment of the boiling heavy water concept, and the containment, which is in a rock cavern excavated from a mountain. It is located adjacent to the premises of a large paper company, Saugbrugsforeningen, in Halden, in South-East Norway, about 80 miles from Oslo and close to the Swedish border. The factory will, in fact, be its customer for steam, when it becomes available.

The general scheme of operation can be seen from the simplified flow diagram and the cut-away drawing on the pull-out facing this page. Heavy water is boiled in the core and the steam is passed through the primary side of a "steam transformer" or main heat exchanger, with light water on the secondary side. Latent heat only is removed from the steam, and the condensed $D_2O$ is returned, with only a slight drop in temperature to the top of the reactor tank. A certain proportion can be drawn from the bottom of the tank, cooled in a sub-cooler heat exchanger, and returned to the tank either at the top or bottom, as required. The main circulation is natural, the sub-cooler circuit is pumped. The flow of water in the reactor will be discussed rather more fully in a later section.

### Reactor Vessel

The main pressure vessel is 2.7 m (8 ft. 10¾ in.) diameter, and 476 cm (15 ft 7½ in.) high from the bottom of the dome to the flange, with a plate thickness of 60 mm (2.36 in.), the material being clad steel, which is also used for the domed bottom. Both the top plate, 700 mm (27.6 in.) in thickness, and the flange are mild steel forgings. The flange is covered with stainless steel deposited by a continuous welding process and subsequently machined; the top plate is nickel plated. Nickel plating is also used for certain internal parts, and is deposited by a chemical

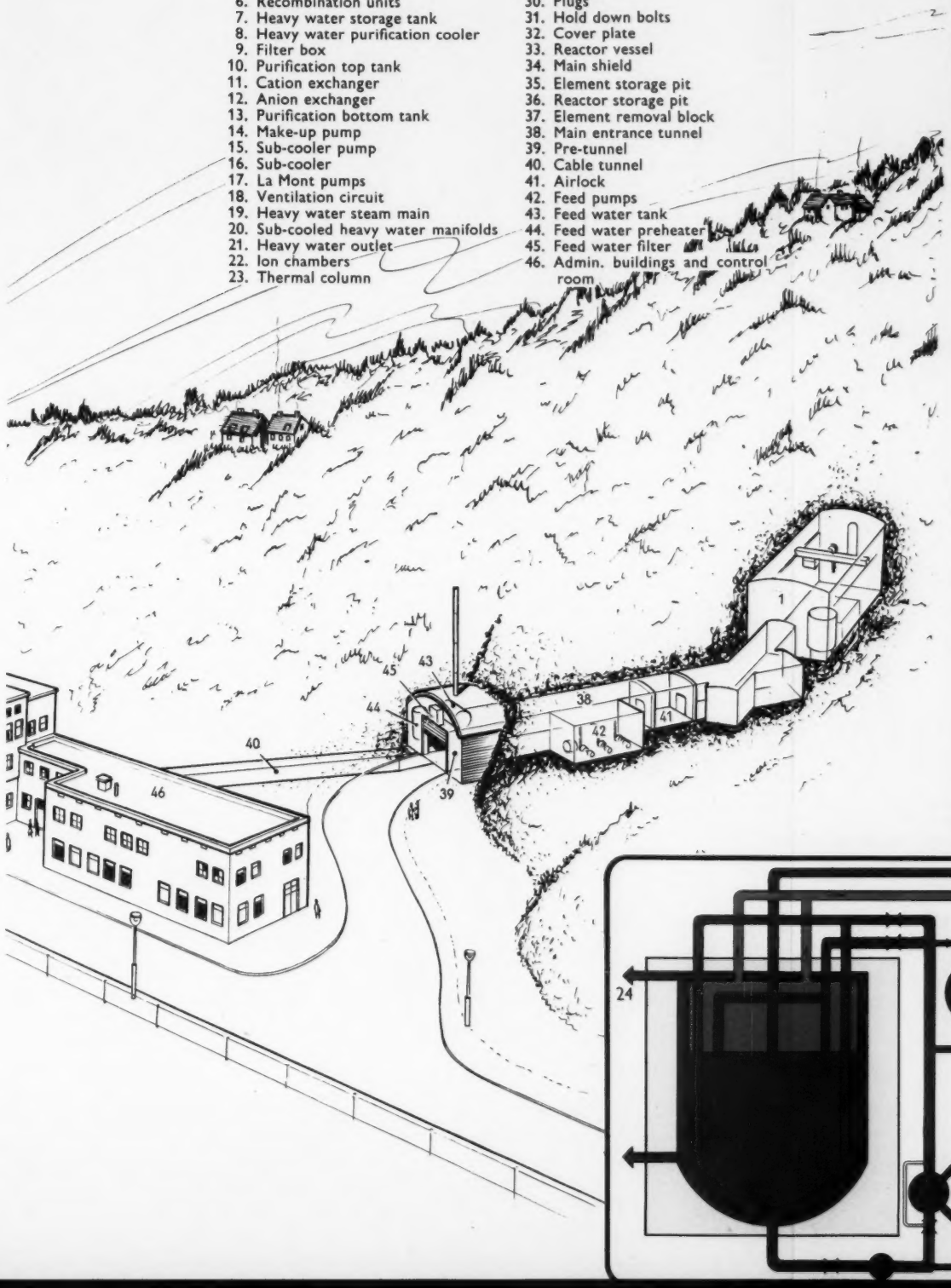
The general view of the Halden scheme above shows the entrance to the pre-tunnel with administration buildings and control room in the foreground.

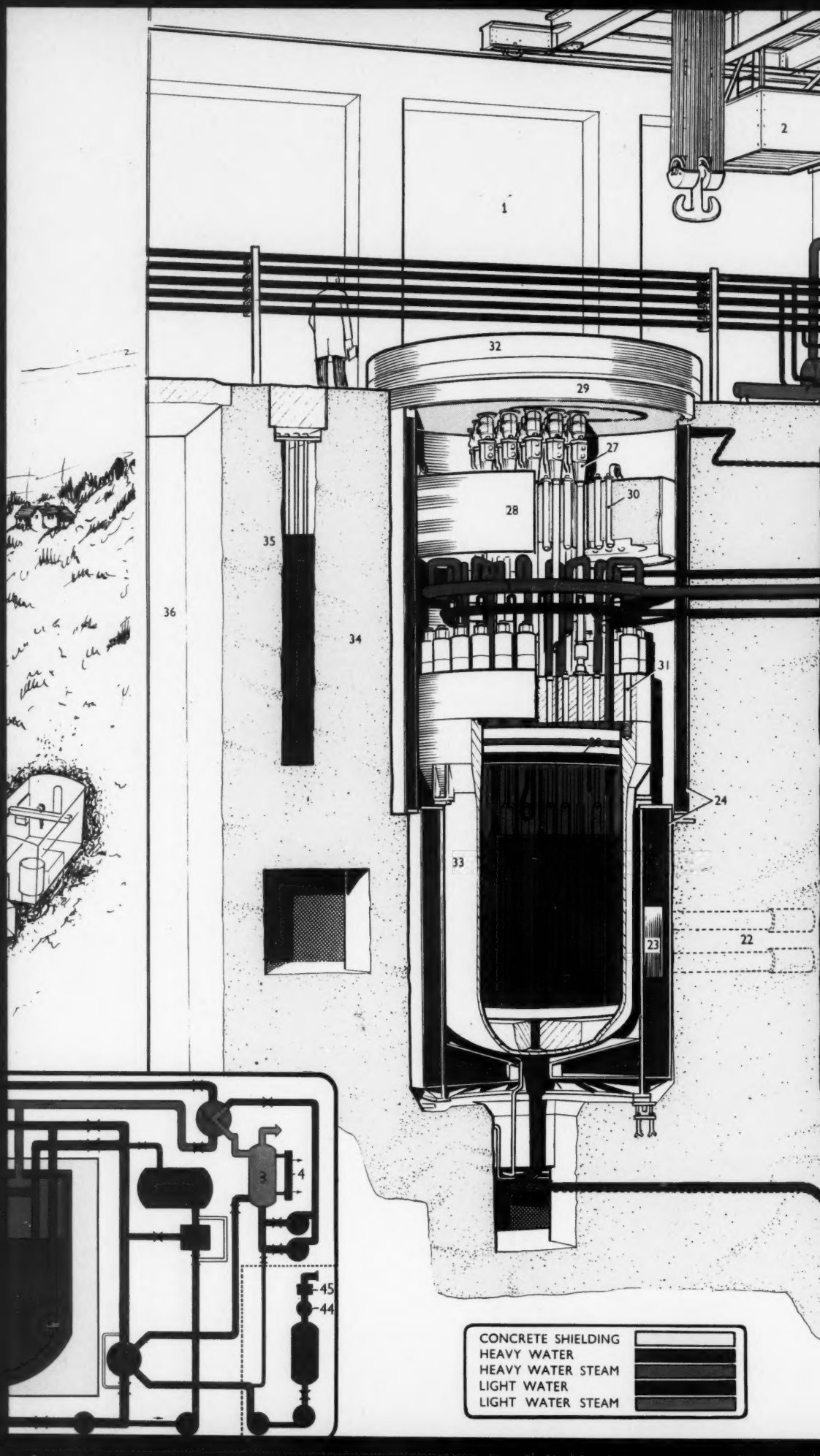
# The World's Reactors

## No. 21 HALDEN

**KEY**

1. Reactor hall (unmanned during operation)
2. Travelling crane
3. Steam drum
4. Electric heaters
5. Heat exchanger
6. Recombination units
7. Heavy water storage tank
8. Heavy water purification cooler
9. Filter box
10. Purification top tank
11. Cation exchanger
12. Anion exchanger
13. Purification bottom tank
14. Make-up pump
15. Sub-cooler pump
16. Sub-cooler
17. La Mont pumps
18. Ventilation circuit
19. Heavy water steam main
20. Sub-cooled heavy water manifolds
21. Heavy water outlet
22. Ion chambers
23. Thermal column
24. Shield coolant circuit
25. Core
26. Control rods
27. Control rod drives
28. Top shield
29. Access plates
30. Plugs
31. Hold down bolts
32. Cover plate
33. Reactor vessel
34. Main shield
35. Element storage pit
36. Reactor storage pit
37. Element removal block
38. Main entrance tunnel
39. Pre-tunnel
40. Cable tunnel
41. Airlock
42. Feed pumps
43. Feed water tank
44. Feed water preheater
45. Feed water filter
46. Admin. buildings and control room

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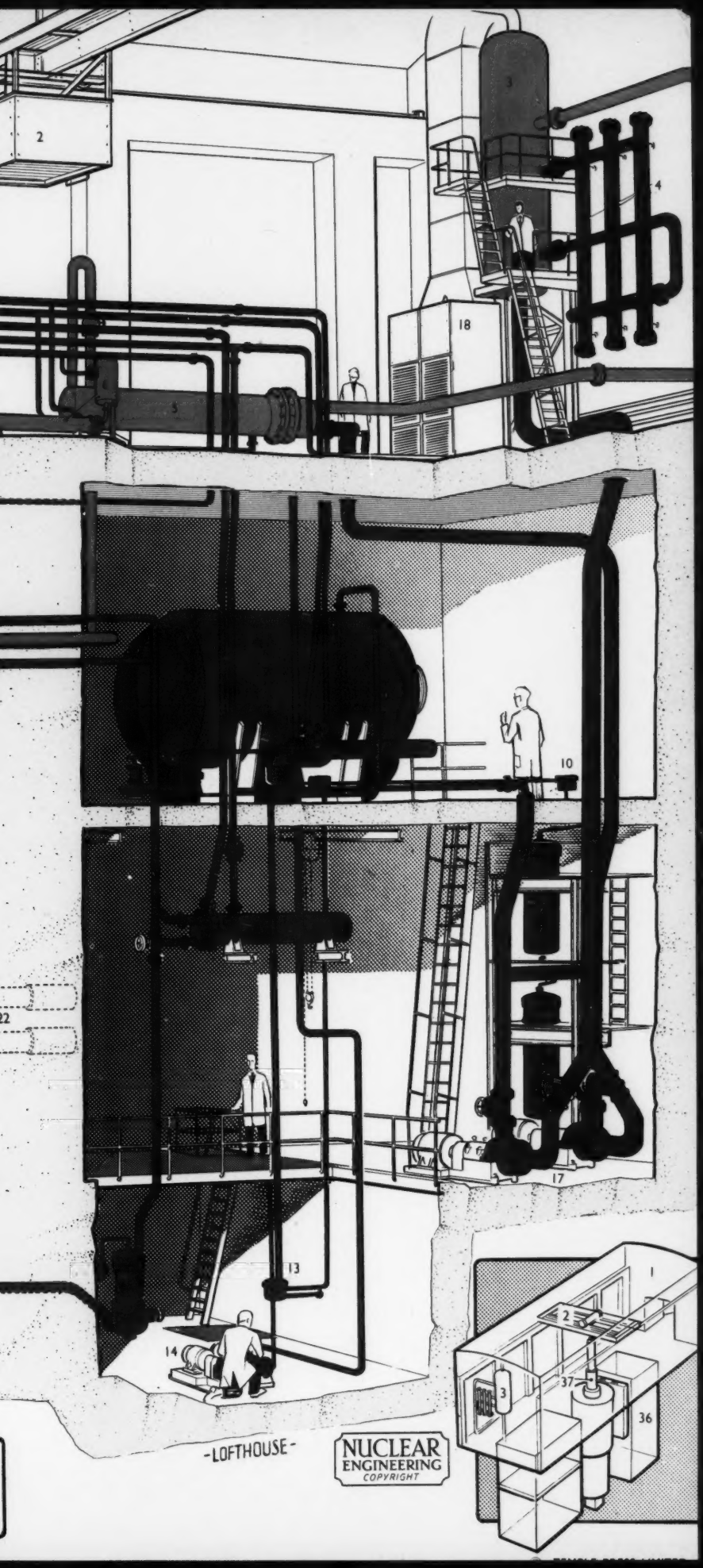
CONCRETE SHIELDING
HEAVY WATER
HEAVY WATER STEAM
LIGHT WATER
LIGHT WATER STEAM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# The World's Reactors

## No. 21 HALDEN

**TYPE:** Thermal heterogeneous (boiling heavy water).

**PURPOSE:** Mainly experimental; some process steam production at later date.

**LOCATION:** Halden, S. E. Norway.

**OWNER:** Institutt for Atomenergi.

**OPERATION:** Criticality scheduled: March, 1959.

**RATING:**
5 MW, with first core.
10 MW, with second core; 20 MW at later date.

**FUEL ELEMENTS:**
First core: Natural uranium cylindrical rods, Al clad.
Spiked by s.s. clad, $UO_2$ rod clusters.
Rod diameter: 25 mm.
Rod length: 2.4 m U; overall 4.9 m.
Cladding: finned tube, 2 mm wall.
Total number of rods: 316.
Second core: enriched $UO_2$, s.s. clad.

**CORE:**
Hexagonal lattice, 130 mm pitch.
Provision for 325 elements.

**MODERATOR COOLANT:**
Heavy water.
Investment: 16 tonnes; 15 tonnes in core tank.
$D_2O$ boils in core, latent heat removed in heat exchanger.
Up to 15% can be withdrawn from tank bottom.
Following figures refer to rating of 10 MW:
Operating pressure: 28 kg/cm² (400 p.s.i.).
Outlet temperature (steam): 230°C.
Inlet temperature (condensate): 220°C.
Steam loop circulation: 20 tonnes/h (74 gal/min).
Subcooled $D_2O$ temperature: 200°C.
Subcooled $D_2O$ flow: 80 m³/h (294 gal/min).

**SECONDARY COOLANT:**
Light water.
Temperature: 185°C.
Pressure: 17.5 kg/cm² (250 p.s.i.).
Steam output: 15 tonnes/h.
Main heat exchanger surface: 133 m².
Sub-cooler surface: 8.5 m².

**FLUX:** Thermal peak: $3 \times 10^{13}$ n/cm², sec.

**CONTROL:**
19 shim/scram, 1 fine control.
Construction: cadmium tubes, s.s. clad.
Dimensions: 1800 mm × 51 mm o.d.
Reactivity controlled: 1.5% $\Delta k/k$, each shim/scram;
0.3% $\Delta k/k$, fine.
Drives: shim/scram: 2 speed, 3 ph, induction motors;
rod speed 12.5, 1.5 mm/sec;
fine: 2 ph induction motor;
rod speed: 0–25 mm/sec.

**CONTROL REQUIREMENTS:**

| | |
|---|---|
| Xe and Sa | 3% $\Delta k/k$ |
| Temp. compensation | 8% $\Delta k/k$ |
| Voids | 1% $\Delta k/k$ |
| Operation and burn-up | 2% $\Delta k/k$ |
| Total | 14% $\Delta k/k$ |

**REACTOR TANK:**
Vessel: s.s. clad plate.
Dimensions: 475 cm high (less closure) × 270 cm i.d., 6 cm wall.
Cladding: 5 cm thick.
Closure: 343 cm × 70 cm thick.
Design pressure: 40 kg/cm² (570 p.s.i.).
Test pressure: 56 kg/cm² (800 p.s.i.).

**SHIELDING:**
Side thermal: 37 cm water.
Side biological: 235 cm concrete.
Top: 82 cm concrete in iron.
Cover plates: 23 cm steel.

**REACTOR HALL:**
Dimensions: 28 m × 10 m × 11.4 m high.
Entrance tunnel: 60 m.
Total rock removed: 8,000 m³.

rch, 1959

er date.

*Data sheets in this series already published in " Nuclear Engineering " are:*

*No. 1. BEPO (April, 1956)*
*No. 2. CP5 (May, 1956)*
*No. 3. NRX (June, 1956)*
*No. 4. DIMPLE (August, 1956)*
*No. 5. ZEUS (September, 1956)*
*No. 6. CALDER HALL (October and December, 1956)*
*No. 7. RUSSIAN 5 MW (November, 1956)*
*No. 8. DIDO (January, 1957)*
*No. 9. THE SOUTH OF SCOTLAND ELECTRICITY BOARD STATION (February, 1957)*
*No. 10. BERKELEY POWER STATION (March, 1957)*
*No. 11. BRADWELL POWER STATION (April, 1957)*
*No. 12. DOUNREAY FAST REACTOR (June, 1957)*
*No. 13. EBWR (July, 1957)*
*No. 14. RWE 1 (September, 1957)*
*No. 15. LIDO (November, 1957)*
*No. 16. PLUTO (April, 1958)*
*No. 17. MERLIN (May, 1958)*
*No. 18. G1 (June, 1958)*
*No. 19. HINKLEY POINT POWER STATION (July, 1958)*
*No. 20. NRU (February, 1959)*

.. 3% $\Delta k/k$
.. 8% $\Delta k/k$
.. 1% $\Delta k/k$
.. 2% $\Delta k/k$

.. 14% $\Delta k/k$

wall.

The control room at Halden is located next to the administration building outside the reactor hall. A large proportion of the instruments were supplied by British companies.

process. It is considered that for parts in constant contact with steam, nickel is to be preferred, since the risk of attack due to traces of chlorine is less.

The general arrangement of the reactor is shown in Fig. 1. Below the top plate proper, are three further horizontal plates which just fit into the tank, are of nickel-plated mild steel, and have thicknesses of 158 mm (6.25 in.), 100 mm (3.94 in.) and 35 mm (1.38 in.) respectively. Between the lower pair of the three, there is a manifold header, of stainless steel tubing, which distributes the sub-cooled water to 24 downcomer tubes leading to a point just below the level of the heavy water in the tank.

The core bottom is made up of two circular plates, 130 mm (5.12 in.) and 10 mm (0.4 in.) separated by a spacer ring, to provide a plenum chamber for the sub-cooled water from another set of 12 downcomers. The thicker plate has holes on the same lattice centres as the three top shield plates and the tank top, i.e., a hexagonal lattice of 130 mm (5.12 in.) for receiving fuel elements, control rods, or thermometer pockets.

The joint between the vessel and the top plate includes a pair of concentric aluminium gaskets. There is a rebate between the two connected to the $D_2O$ leak system. The joint is held by a massive stud system, with 32 studs each of 142 mm (5.6 in.) diameter having nuts nearly 250 mm (9.9 in.) across the corners. The system was tightened by heating the studs which have built-in heating elements for the purpose, and screwing down to a predetermined tightness while hot.

Situated below the lower core plate is a steel block of plano-convex shape, practically filling the domed end of the pressure vessel. Its function is purely to act as a filler piece, to reduce the investment of heavy water, and it is in boiler steel nickel plated.

All steam piping in the $D_2O$ system is in mild steel, nickel plated internally.


Réacteur à Eau Bouillante de Halden

*D'après le programme établi, le réacteur à eau lourde bouillante expérimental construit à Halden, en Norvège sud-orientale, doit devenir critique sous peu. Il s'agit ici du seul réacteur en son genre au monde et sa puissance nominale, avec son premier noyau, est de 5 MW. Le second noyau portera cette puissance à 10 MW et, plus tard, on s'attend à une nouvelle augmentation à 20 MW.*

*Bien que ce réacteur ait été essentiellement conçu aux fins d'essais, le nécessaire y a été prévu pour la distribution de la vapeur d'extraction produite à une papeterie avoisinante.*

*La description complète du réacteur et des circuits de refroidissement primaires et secondaires associés est donnée dans ce numéro où on trouvera aussi une discussion de la méthode nouvelle de sa construction—la salle du réacteur ayant été creusée à même la roche.*

Siedewasser-Reaktor in Halden.

*Der mit schwerem Wasser arbeitende Siedewasser-Reaktor, der in Halden in Sudost-Norwegen gebaut wird, soll programmgemäss demnächst kritisch werden. Er ist der einzige Reaktor dieses Types in der Welt, die Leistung mit seinem ersten Kern soll 5 MW betragen. Der zweite Kern wird die Leistung auf 10 MW erhöhen und für später ist eine weitere Erhöhung auf 20 MW geplant.*

*Obwohl im wesentlichen nur experimentell, so ist doch vorgesehen, dass der im Betrieb erzeugte Dampf zu einer in der Nähe gelegenen Papierfabrik geleitet wird.*

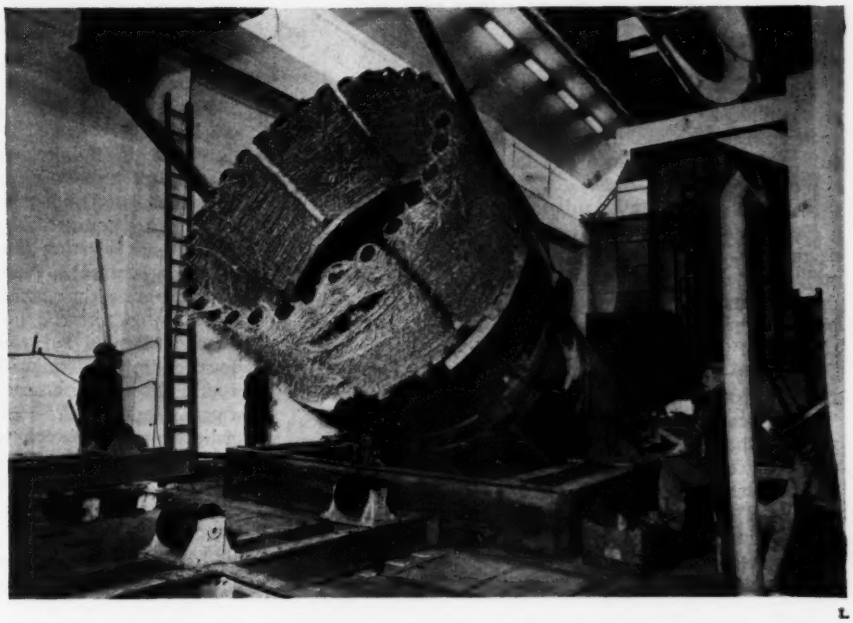
*Es wird eine ausführliche Beschreibung des Reaktors und der zugehörigen primären und sekundären Kühlmittel-Umläufe gegeben, und weiter die neue Konstruktionsmethode die Reaktorhalle ist aus dem gewchsenen Felsen herausgearbeitet worden—diskutiert.*

Reactor de Agua Hirviente de Halden

*El reactor experimental de agua pesada hirviente construído en Halden, en el sureste de Noruego, está programado a volverse crítico dentro de breve. Este es el único reactor de su tipo en el mundo y, con su primer núcleo, está clasificado para desarrollar 5 MW. El segundo núcleo aumentará esta capacidad a 10 MW y, más tarde se anticipa un aumento adicional a 20 MW.*

*Aunque esencialmente experimental, se han hecho arreglos para la distribución del vapor procesado producido a una fábrica de papel cercana.*

*Se ofrece una amplia descripción del reactor y de los circuitos asociados de enfriamiento primarios y secundarios, y se discute el nuevo y original método de construcción, ya que la sala del reactor ha sido excavada en la roca viva.*

Lowering the reactor vessel into position in the reactor pit. The framework over the pit is temporary.

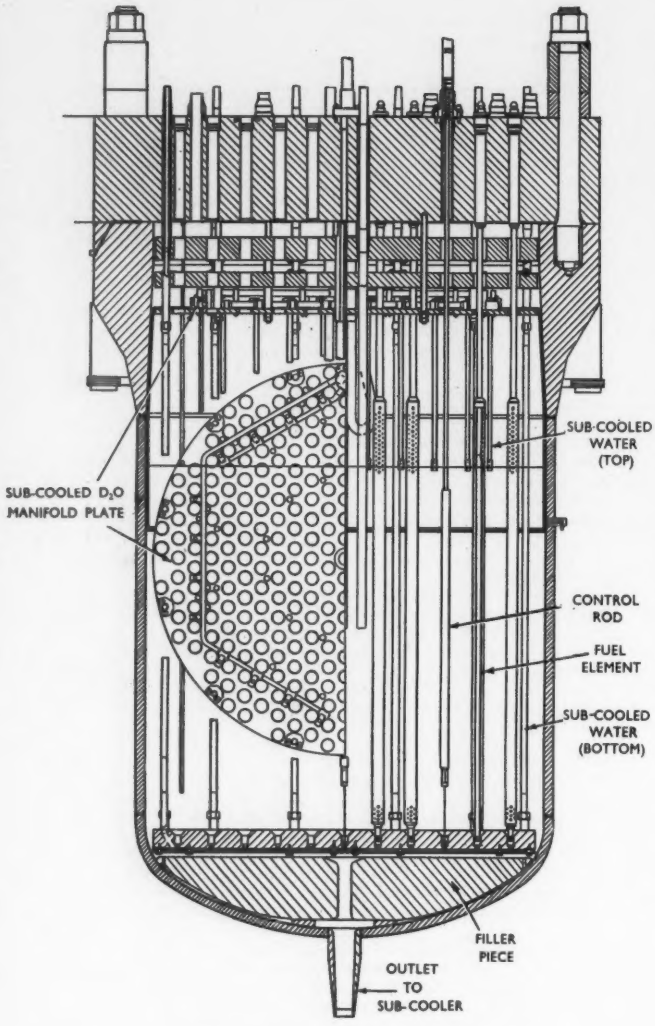



Fig. 1.—Section through reactor vessel.

## Core

One of the conditions laid down by the U.K. AEA, who supplied them, was that an exact description of the fuel elements should not be published. However, it is sufficient to say that they are of fairly conventional design, comprising uranium rods, 25 mm diameter, 2.4 m long, clad in finned aluminium tubes.

End fittings on the fuel elements are arranged so that, at the top, the elements provide their own seal, with a spring-loaded seating against the top plate. At the bottom, the elements are provided with ends fitting into the bottom plate; each element has holes drilled at an angle so that sub-cooled water entering from the plenum chamber formed by the space between the plates is distributed radially from the bottom of the element.

Fuel elements are fitted with concentric shrouds with ports in the lower portion and perforations at the top to allow of free inlet of $D_2O$ and outlet of steam. The shrouds can be removed from the elements through the top plate, as required, and will enable a wide range of experimental work to be carried out on flow patterns, with the upstreaming water-steam mixture inside the shroud and the down-streaming heavy water outside; particularly when combined with the possibilities for further variation by the introduction of sub-cooled water at top or bottom. The flow pattern obtained in the reactor is one of the subjects that has been selected for intensive study, variations being introduced not only by removal of shrouds and changes in the position of introduction of the sub-cooled water, but by variation in the type of nozzle at the bottom of the fuel element. In theory, the boiling reactor has a comparatively large negative temperature coefficient of reactivity for steam voids; one of the most fertile fields of experiment will be the co-relation of steam voids and reactivity.

Although the operating temperature scheduled for the reactor in its final state is 250°C (482°F) the first fuel charge must operate at a much lower temperature to avoid corrosion problems, and a limit of 150°C (302°F) has been set for the first fuel charge. This, it is considered, will not be achieved with natural uranium alone, and a "spiking" of the core is envisaged by fuel elements consisting of enriched uranium oxide pellets, in small-diameter tubes arranged in cluster formation, utilizing stainless steel canning. The second charge for full working conditions, will, it is expected, be of slightly enriched uranium oxide, canned in stainless steel, throughout. It is expected that the spiking experiments will provide valuable information towards specifying the second core.

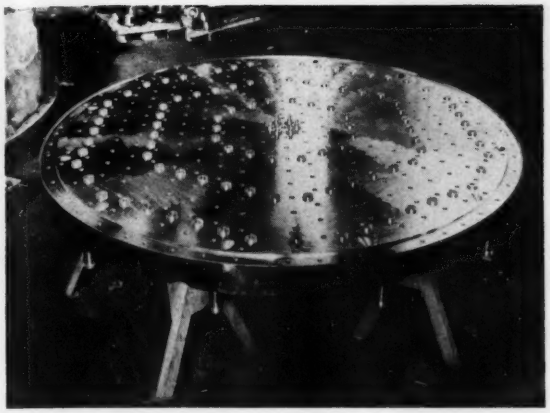
## Control

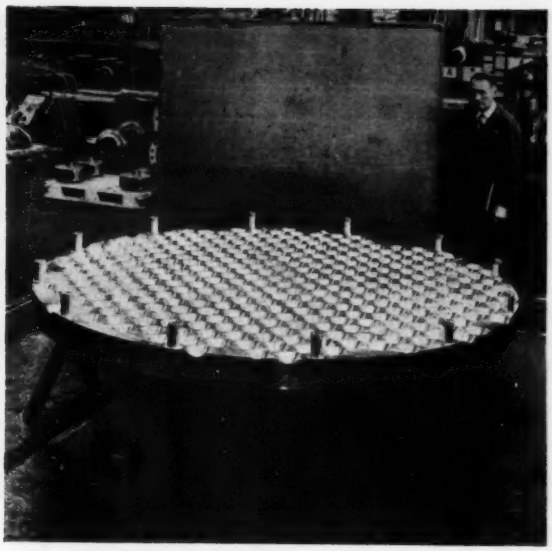
The control gear for the Halden reactor is described elsewhere† in considerable detail, and a brief summary must suffice here. Nineteen rods are envisaged for shim and scram, with an additional fine control rod.

The design problems faced are quite considerable. The piston action of the rods rules out the use of gland-type seals at the operational pressures envisaged, because of the inevitable leakage and excessive friction. On the other hand, the enclosure within a pressurized thimble of any type of control rod, makes operation and accurate indication very difficult.

The Halden reactor has control rods of cadmium, the entire control rod being enclosed inside a non-magnetic pressure thimble on top of the reactor, to take care of the pressure-containment problems. Operation is by means of a magnetic coupling between an iron plunger on the rod and a solenoid coil sliding up and down outside the pressure thimble, as determined by the required setting. The operating mechanism is driven by an induction motor, with pole-changing two-speed control giving motor speeds of 2,950 and 326 r.p.m., corresponding to rod speeds of 12.5 and 1.5 mm/sec. (Fine control rods have a two-phase motor and have an infinitely-variable speed of 0-26 mm/sec.) The control mechanism drives through suitable gearing a pair of insulated pulleys, on which are wound flexible bands of beryllium copper. These perform the dual function of raising and lowering the solenoid coil and carrying the energizing current. When the solenoids are de-energized for scramming, the rods are dropped; otherwise the plunger at the top of the rod faithfully follows the coil. Micro-switches located on top of the solenoid magnetically operated by the fringe flux of the coil indicate if there should be any discrepancy between the position of the solenoid and the rod it is controlling. There are two distinct plunger designs for the main rods and the fine control; the latter, requiring an accuracy of positioning even higher than that of the shim rods, has a series of roller bearings so that a minute amount of inaccuracy in centring the core should not lead to unbalanced forces tending to

† "The Halden Boiling Heavy Water Reactor," by Nils Hidle and Odd Dahl. Geneva, 1958. Ref.: P./559.





(Above) Underside of the bottom lattice plate.
(Right) Bottom lattice plate showing fuel element reception holes and twelve stubs for return pipes from second sub-cooled $D_2O$ ring main.

pull the core sideways and increase the friction loading. Molybdenum disulphide is used as a lubricant for both shim and fine control rods.

An interesting feature of the control mechanism is the arrangement for a controlled leak in the containment thimble, to prevent the accumulation of a detonating mixture of dissociated gases. The use of a plain orifice was not practicable, an orifice small enough to give a power loss within acceptable limits would rapidly choke up. The problem was solved by the use of porous stainless steel filters made by Metal and Plastic Compacts, Ltd. Two filters, a coarse and a fine grade, are used in series, the fine filter providing the necessary pressure drop, and the low-pressure steam is piped back to the heavy water system.

**Heavy Water Circuit**

The actual feeding arrangements to and from the core are not obvious from the various drawings, although Fig. 2 gives a general picture of the top piping systems. Steam is removed by 10 tubes in the top plate feeding what is, in effect, a ring manifold, and passes to the main heat exchanger. Condensate from the heat exchanger is normally distributed by two tubes to just below the water level in the reactor. Sub-cooled water is drawn from the bottom of the tank and returned either to a ring manifold above the top plate which distributes it via 12 tubes to the plenum chamber at the bottom of the reactor or, by closing one valve and opening another, the sub-cooled water can be distributed to the top of the reactor, just below water level, by the ring manifold referred to in an earlier section. There are, therefore, three ring manifolds, two being above the reactor for steam and sub-cooled water respectively, and another in between the second and third top core plates for the alternative sub-cooled water inlet.

The main $D_2O$–$H_2O$ heat exchanger, or steam transformer, is located in the main hall, above reactor level. It is of the shell and tube type, with a diameter of 850 mm (2 ft 9¼ in.) and an overall length of 5 m (16 ft 4¾ in.), the heavy water being in the shell and the light water in the tubes. The total area of the heat exchanger is approximately 133 m² (1,430 sq. ft) and is in stainless steel throughout. The light water tubes are in loop formation and are rolled and welded into the single header, thus practically eliminating the expansion troubles that might occur with a straight-tube unit.

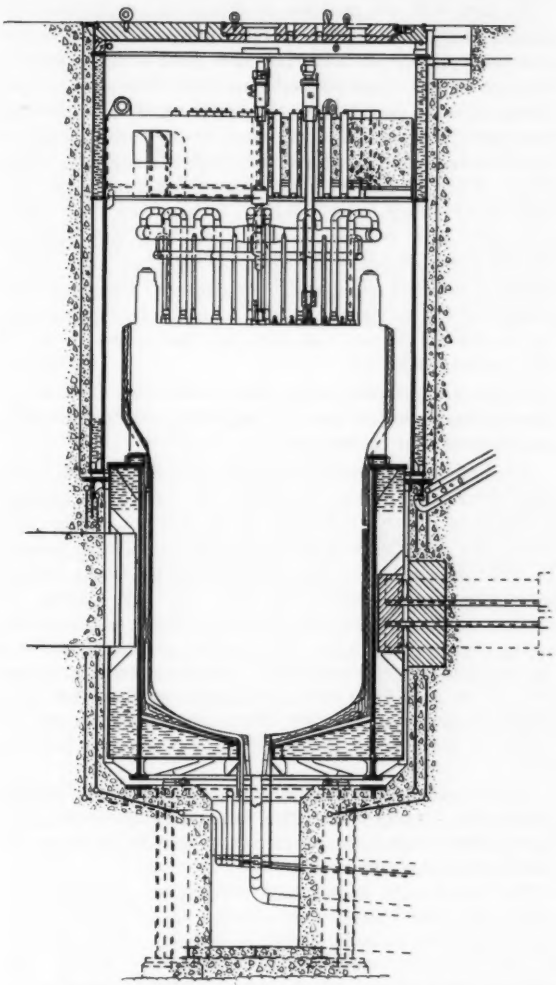
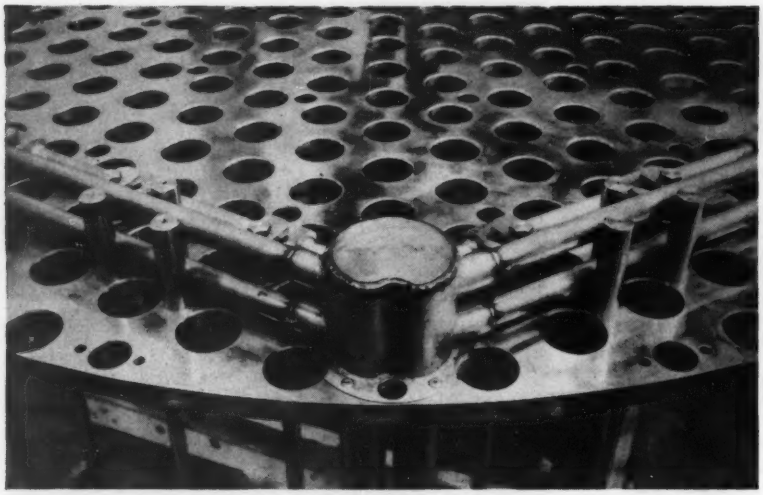
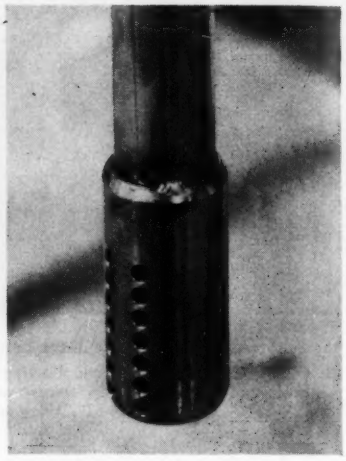


Fig. 2.—General arrangement of reactor vessel in reactor pit, showing pipework connections.



Third (lowest) manifold returning sub-cooled $D_2O$ to just below the level of $D_2O$ in reactor vessel.

Lower end of pipe returning sub-cooled $D_2O$ to reactor vessel.



To deal with the problem of dissociated deuterium and oxygen there are two recombiner units, for high-pressure and low-pressure service. The H.P. feed is taken from a tapping on the drum of the main heat-exchanger. After reheating in an electrical heater unit the gases pass through the recombination unit and return to the steam circuit at the low-pressure point of a venturi orifice in the main steam pipe. The L.P. recombination unit is fed directly into the main $D_2O$ storage tank, which is located one floor below the main floor of the reactor hall. The sub-cooler is located one floor below the main $D_2O$ storage tank; and is, again, of the shell and looped-tube pattern. The circulating pump for the sub-cooler circuit is of the canned pattern, by Hayward Tyler and Co., Ltd., and has a through-put of 294 gal/min ($80m^3/h$).

Valves are provided in the heavy water circuit for by-passing the sub-cooler and for controlling the flow to either top or bottom of the reactor.

The high cost of heavy water necessitates the most stringent precautions against leakage. All valves are bellows sealed, and on the L.P. side of the bellows, manometer alarms are provided to give warning of any bellows failure. In addition all valves have double stuffing boxes with a drain chamber in between the H.P. and L.P. glands. A number of the smaller needle valves on the minor heavy water circuits have been converted to double-gland type by the Halden staff themselves, from commercial stainless steel valves supplied with a special long stem; this has been found a simpler procedure than either ordering special valves or making up complete valves from scratch, as it were.

Other precautions against leakage include the use of "Metalflex" gaskets in flange joints and surrounding all flange joints with boxes connected to the $D_2O$ system and monitored for alarm.

The heavy water circuit has, of course, a complete filter and treatment plant, with anion and cation resin exchangers, fed through a small cooler unit. Purified water is returned to the main circuit by a "Lapp" pump. The storage tank, located approximately midway between the main heat exchanger and the sub-cooler unit, has a capacity of 17 $m^3$ (3,740 gal).

**Light Water Circuit**

The Halden water is of good quality and after filtering, passes to the various low temperature secondary coolers for the $D_2O$ purification loop and the shield cooling circuit. It then passes through two preheater stages to the feed tank where it is boiled at 100°C (212°F) for de-aeration. Two high-pressure feed pumps then force it against the steam drum pressure of 17.5 kg/cm² (250 p.s.i.) through the sub-cooler circuit where it is heated to 185°C (365°F) and passes to the steam drum of the main heat exchanger system. The secondary side of the main heat exchanger is, in effect, a Lamont boiler, with continuous circulation by two Bahlke pumps, the steam separating from the steam-water mixture in the drum and discharged to atmosphere by dummy load valves. It will be passed to the Saugbrugsforeningen paper factory steam system, when testing is complete and the reactor is available for commercial operation. Electric heaters are also provided and are mounted alongside the drum, for starting-up purposes.

**Containment**

As previously mentioned, the entire installation, with the exception of the control room, is contained in the solid rock. The economics of this have been queried but it has been shown‡ that in Norway, at least, where excavation techniques are well known, this type of containment differs very little in costs from those of a conventional building, and is considerably cheaper than a steel containment such as a sphere.

The main hall is rectangular in shape with an arched roof. The maximum width of the hall was fixed by the quality of the rock, and is 10.5 m (34 ft 7¼ in.) with a length of 30 m (98 ft 5¼ in.) and an overall height of the excavation at the centre of the roof span of 26 m (85 ft 3½ in.), this dimension being fixed by the lifting requirements.

The main hall is lined throughout with concrete, which is also used for the flooring and foundations for the reactor. The height from the finished floor level to the roof is 11.4 m (36 ft 6 in.) and from the floor level to the lowest sump is 12.49 m (41 ft 0 in.). The actual foundations contain three deep pits, one for the reactor, one for the auxiliary equipment and one which is intended for dumping

‡ "Underground Location of a Nuclear Reactor," by N. G. Aamodt, Jener, Kjeller, Norway, Geneva, 1958. Ref.: P.561.

the reactor core should major changes be decided, i.e., should it be necessary to operate with a different core lattice. Other plans have since been made for this, as will be described later in the section on fuel handling. There is also a shallower rectangular pit for fuel element storage.

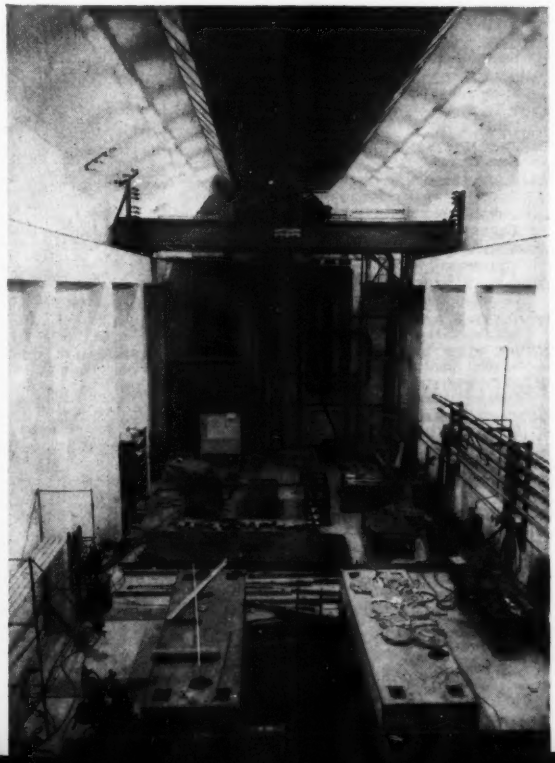
From the reactor hall, which has a minimum rock coverage of 30 m (98 ft 5¼ in.) and a maximum of 60 m (196 ft. 10½ in.) a tunnel with a total length of 59.5 m (195 ft) leads to the open air. A portion of this is, in effect, a " pre-tunnel " or manufactured tunnel, constructed with concrete arches.

Between the mouth of the tunnel and the reactor hall is an airlock 7 m (22 ft 11¾ in.) long with concrete walls 1 m (3 ft 3¾ in.) thick, and heavy steel doors, electrically interlocked. This airlock is expected to contain any fission products that might be released in the event of an excursion, in fact it is expected to be explosion-proof and extreme care has been taken with the sealing of pipes and cables passing through it, and quick-acting valves are provided on the ventilation trunking.

The method of sealing the control cables is particularly interesting, as they are p.v.c. sheathed, to which it is difficult to obtain adhesion, and the cables require internal sealing, of course. In the case of multi-core single-strand construction it has been sufficient to cut the sheath away for a length of about 3 in., " birdcage " the cores and cast an elliptical lump of " Araldite " epoxy resin around the whole, adhesion being obtained by first coating with a commercially-obtainable glue. The general appearance of the finished seal is similar to that of a wiped joint on a lead-covered cable sheath. In the case of cables with stranded cores, it is necessary to cut back the insulation and seal each core individually, afterwards making the same type of seal on the whole core. The cables pass through the walls of the airlock in precast concrete slabs having slots curved in a lengthwise direction in a shallow U. These slots are filled with sand to act as a support for the seal proper, a layer of a neoprene compound floated in at each end, and given mechanical protection by a further layer of Araldite.

It is planned to give the complete enclosure (which, when we saw it, was nearing completion with the casting of the airlock walls) a pressure test, to determine the leakage rate.

Interior of reactor hall, looking towards steam drum.



**Layout of Plant**

The general arrangement of the plant will be clear from the various illustrations. A rather surprising feature, at first glance, is the location of the feedwater filters, tank, and preheaters in the pre-tunnel portion of the plant, and the feed pumps a short distance inside the tunnel proper, thus triplicating the piping required, since the water after passing the filters has to enter the reactor hall to pass through the low-temperature coolers, and then return almost to the tunnel mouth for preheating and de-aeration prior to the feed pumps, after which it returns to the reactor hall. It was pointed out, however, that this arrangement saves a considerable amount of space in the reactor hall and can be justified on economic grounds. Furthermore, it leaves the pumps, tank, preheaters and filters outside the airlock, and easy of access. It is expected that the reactor hall will be unmanned and closed-circuit television will be used for supervision of operation.

The reactor tank rests within a cooling and support structure which is, in effect, a large-scale water jacket in two portions, upper and lower. Both portions, like the main pressure vessel were made by Kvaerner Brug of Oslo.

The installation of the pressure vessel proved to be one of the most difficult problems of the whole erection programme. It had originally been planned to tow the trailer carrying the vessel into the reactor hall by a " mechanical horse "-type of tractor, but space limitations inside the hall prevented this and it was necessary to *push* the trailer in, so that the skill required in navigating the bend in the tunnel can well be imagined. The vessel was first placed by means of the crane, horizontally on to a temporary girder framework erected over the reactor pit carrying a pair of half-bearings, into which trunnions fitted on the reactor tank were placed, and by means of a second pair of trunnions, the vessel was swung from a horizontal to a vertical position. The stubs that had acted as trunnions were next cut off and the vessel, half in its pit and vertical, was raised by the crane and the temporary framework dismantled. The vessel was then lowered into position.

**Shielding**

As can be seen from the various illustrations, there is full shielding between the vessel pit and the adjacent basement for auxiliary machinery, the wall being solid except for a number of cylindrical holes left for ion chambers.

Top shielding is by means of a circular precast steel-and-concrete shield 82 cm (2 ft 8 in.) thick, which is provided with an accurately-cast cored hole system for the fuel elements and the control rods. Above this there is an air space, and then the reactor top shield, which consists of a steel top plate 23 cm (9 in.) thick, having an eccentric hole carrying another plate also having an eccentric hole. Both plates rotate on ball bearings, so that the small hole in the second plate can be located over any fuel element in the reactor.

The concrete is cooled by a system of pipes cast in place when the reactor pit was prepared.

**Fuel Handling**

The fuel element flask is handled by the crane of fairly conventional design so far as the element grabbing and shielding is concerned. One noteworthy feature, however, is a proposed inspection device which fits on top of the reactor between the top plate and the flask. By means of a system of mirrors and periscopes, the element can be examined while being hauled up into the flask.

A further proposal, now under investigation for the critical examination of fuel elements, is to utilize the spare core dumping pit as a wet inspection and storage pit for

fuel elements. These, hanging vertically, would be slowly rotated and examined by means of a periscope, which would have a vertical travel equal to the entire active length of the element, and thus enable close inspection of the entire surface. This pit, it is also proposed, would be used in conjunction with an under-water saw for cutting off the end fittings of irradiated elements, to facilitate their transport in lead coffins to Kjeller for subsequent chemical processing.

**Waste Disposal**

Halden has no facilities for dealing with active waste, and none are contemplated, for the present, at least. Water which is either spilled or drained from any part of the system eventually drains into a sump from which it is pumped by one of two pumps to delay tanks located near the tunnel mouth and, after monitoring, can be discharged to the town drainage system. In case of emergency, and should the tanks be full, the deep pit under the reactor vessel can be utilized.

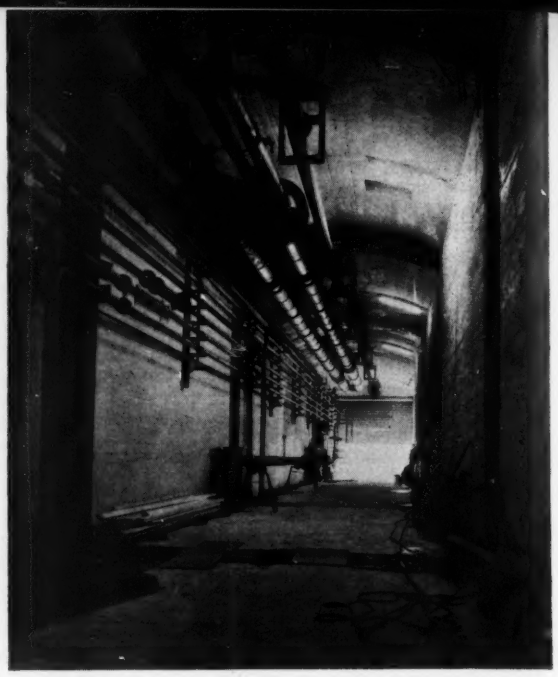
**Ventilation**

Ventilation in the hall is taken care of by fans in the tunnel; the quick-acting valves for closing the air trunking in emergency have already been mentioned. The air is passed into the hall at the right-hand side of the large plenum chamber on the roof of the main reactor hall. A further ventilation unit recirculates air via monitored filters via the outlets on the left-hand side of the plenum chamber. Air is also delivered to the underfloor compartments containing the auxiliaries. Air is discharged from the hall by a duct along the tunnel filtered and monitored, and discharged to atmosphere.

**Control Room**

The premises at Halden form an extension to the office buildings of Saugbrugsforeningen and, in fact, utilize a common entrance hall and staircase. The control room is at ground level and contains the desk-type panel from which actual operation is organized with the rod selector switches, operating and scram push-buttons, and position control indicators; the upright panels facing the control desk carry recorders and process instruments. There is a large mimic diagram, with indicating instruments. The diagram includes a vertically-moving fine control rod driven from a relay servo and following the movement of the actual rod. It also operates limit switches towards either end of its travel, to operate the shim rods, to bring it back within its normal working range.

The relays and all other gear are located in the basement beneath the control room; the cable tunnel opens directly into this basement thus facilitating the task of making neat and orderly arrangement for the cable runs and racking. The battery room adjoins the basement.



The main entrance tunnel, looking towards the exit.

## Provisional List of Contractors

**THUNES MEK. VÆRKSTED A/S, Drammensveien 130, Oslo**
Complete secondary system including main heat exchanger, $D_2O$ storage tank.

**KVÆRNER BRUG A/S, Enebakkveien 65, Oslo**
Complete primary system including reactor tank; doors; air lock.

**C.H.R. MICHELSENS INSTITUTT, Nygårdsgaten 114, Bergen**
Graphic panel; control rods.

**HÖYER-ELLEFSEN A/S, Tollbugaten 30, Oslo**
All civil engineering.

**U.K.AEA INDUSTRIAL GROUP, Risley, Lancs.**
Fuel.

**U.S.AEC, Post Office Box A, Aiken, S. Carolina**
Heavy water.

**HAYWARD TYLER AND CO., LTD., P.O. Box 2, Luton**
Heavy water pump.

**H. HALVORSEN MEK. VÆRKSTED, Tentergaten 20, Lilleström**
Mechanical components.

**STANDARD TELEFON OG KABELFABRIK A/S, Økern, Oslo**
Cables, relays, rectifiers.

**G. DIKKERS EN CO., N.V., Hengelo, Holland**
Heavy water valves.

**H. BJERVED A/S, Halden**
Pipe working.

**N. JACOBSENS ELEKTRISKE VERKSTED A/S, Göteborggaten 38, Oslo**
Relays.

**EKCO ELECTRONICS LTD., Southend-on-Sea, Essex**
Instruments.

**ISOTOPE DEVELOPMENTS, LTD., Beenham, Berks.**
Instruments.

**KONGSBERG VÅPENFABRIK, Kongsberg**
Control rod thimbles.

**HAMAR JERNSTÖPERI, Hamar**
50-ton crane.

**INGENIÖRFIRMAET THEODOR QUILLER, Stenersgaten 8, Oslo**
Reactor hall ventilation.

**ELEKTRO-GENERATOR A/S, Ö. Vollgate 11, Oslo**
300-kW electric heater.

**PROTON A/S, Rosenkrantzgaten 11, Oslo**
Relays, contactors, electrical work.

**NORSK JUNGNERAKKUMULATORFABRIK A/S, Halden**
Storage battery.

**LAPP INSULATOR CO., INC., Le Roy, N.Y.**
Pump.

**L. UND C. STEINMÜLLER G.m.b.H., Gummersbach, Germany**
Heat exchanger.

**KLOECKNER-HUMBOLDT-DEUTZ AG, Cologne, Germany**
Emergency diesel generator set.

**INDUSTRI-ISOLERING, Drammen**
Thermal insulation.

**HONEYWELL-BROWN LTD., Newhouse, Motherwell**
Instruments, valves.

**DISA ELEKTRONIK, Herlev Hovedgade 17, Herlev**
Closed circuit T.V.

**MÖGLESTUE A/S, Lörenvangen 14, Økern, Oslo**
Stainless-steel parts.

**NORSK ELEKTRISK OG BROWN BOVERI A/S, Ö. Slottsgate 8, Oslo**
Motors, other electrical components.

**ELLIOTT BROTHERS LTD., Lewisham**
Differential pressure transducers.

**GUNNAR F. KJÖLSTAD A/S, Dronningens Gate 24, Oslo**
Fluorescent lamps.

**NORATOM A/S, Cort Adelers Gate 16, Oslo**
Fuel handling equipment.

**F. JÖRGENSEN, Halden**
Pipework.

**OLAF STENBOCK, Halden**
Electrical work, components.

**IKAS A/S, Kongens Gate 2, Oslo**
Thermal insulation.

# NUCLEAR FUEL CYCLES

**Fuel elements in a power reactor are exposed to neutron fluxes which vary from one region to another and also with time. Reactivity considerations necessitate the regular replacement of fuel but if this is done on a continuous rather than on a bulk basis reactivity is conserved and burn-up can be increased.**

AT the Symposium on Nuclear Fuel Cycles arranged by the Institute of Physics in collaboration with the British Nuclear Energy Conference at the Institute of Civil Engineers, January 22, 23, the full proceedings of which will appear in the July issue of the *Journal of the British Nuclear Energy Conference*, the potential advantages of cycling fuel in graphite-moderated power reactors were discussed. Only at the end of the session were practical limitations considered and, although metallurgical problems were mentioned, the Conference concentrated mainly on methods of increasing burn-up when fuel life is limited by reactivity considerations. Up to a point, therefore, the proceedings were somewhat academic, but the prizes offered in terms of lower fuel costs are considerable and a theoretical evaluation of the potential savings is clearly desirable.

### Long Term Reactivity Changes[1]

Reactivity changes in the reactor are caused by changes in the isotopic composition of the fuel elements (Figs. 1, 2). There is an initial short term drop in reactivity, due to the build-up of fission products, but these quickly saturate and following this drop there is an increase up to say +2% $\Delta k/k$ as a result of the plutonium production; after a peak, there is then a progressive drop. Two important points on the curve are the crossover point, where the reactivity returns from this peak to its original value, and the equal area point, where the average change in reactivity is zero, i.e., the area under the hump on the reactivity curve equals the area over the negative section.

Theoretical predictions of the behaviour of fuel elements are difficult to make with any degree of precision. The fission cross-section of $U^{235}$ approximately follows the 1/V law, but in plutonium there are a number of resonances, particularly at about 0.3 eV, i.e., just above thermalization, which introduce complexity into the calculations. A pressing requirement is the evaluation of fundamental

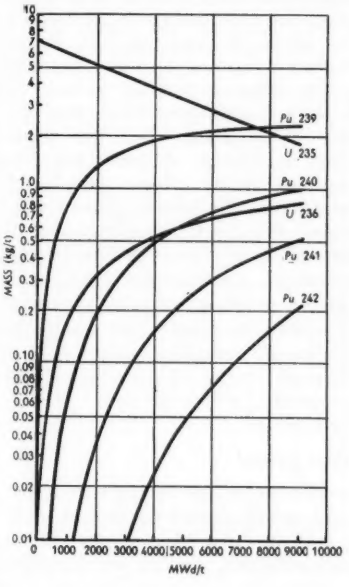



Fig. 1.—Variation of isotopic content of natural uranium with irradiation.

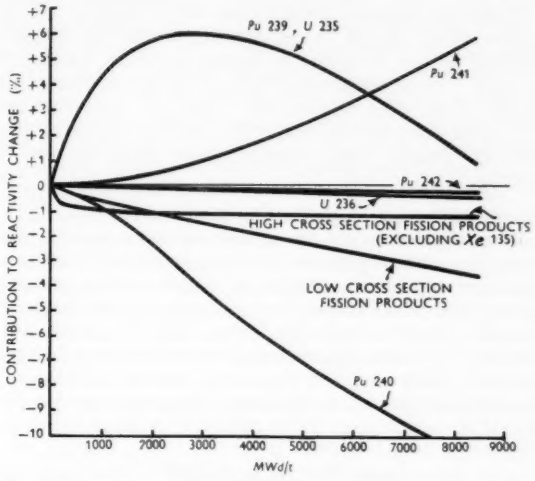



Fig. 2.—Reactivity contribution of important components in a typical fuel element.

constants with an accuracy of 0.1%; lack of these precise data cause an uncertainty in the calculated value of the equal area point of something like 20%.

Although a great deal of effort is being expended on the measurement of nuclear constants, by fitting theoretical concepts to experimental data, spectrum data are sparse and there is a requirement for more intensive work on irradiated fuel elements and for a reactor in which plutonium fuel can be investigated at high temperatures. Useful results are being obtained from pile oscillator measurements made in GLEEP which have been going on since 1953. Measurements have been made on NRX, Windscale and Calder fuel elements but the results require considerable interpretation. Comparisons with theoretical models are, as a rule, only moderately successful. The Canadians have been studying isotopic concentrations spectrographically and they have developed a more sophisticated theory, but on the whole predictions are not much better than those obtained with the GLEEP model. The complication to these measurements is, of course, that all parameters have an effect on the burn-up.

Certain general characteristics, however, can be enumerated. Increasing the conversion ratio, increases the size and duration of the peak in reactivity, while an increase in graphite temperature causes an initial increase in reactivity, but at high burn-ups the difference is small. If the fuel is enriched (to compensate, for example, the

inclusion of steel cans), then the hump decreases, the curve scarcely rising above the base line when enrichment is, say, 1.5% (Fig. 3).

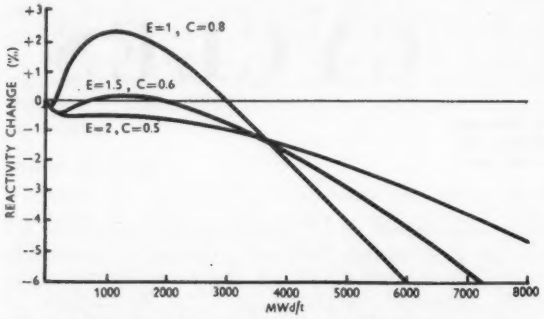



Fig. 3.—Effect of enrichment on reactivity of Calder type reactor.

These are general observations on a Calder reactor system, when applied to one element, overall effects are a function of the variations in parameters from element to element. These integrated effects are being studied in the Calder Hall piles where bulk reactivity measurements have been eased on account of the initial accurate calibration of control rods. Interpretation none the less is difficult.

**Theory of Once-through Fuel Cycles[2]**

In a discussion on the theory of once-through fuel cycles, i.e. cycles in which fuel may be moved but is not processed in between changes of position in the reactor, equations were developed for a simplified model, where in a single region of constant rating, fuel is continuously replaced. If a continuous charge and discharge scheme is operated, such that the fractional rate of exchange is proportional to the instantaneous rating, after an irradiation $M$, an equilibrium value of reactivity given by:

$$y(M) = \frac{1}{M}\int_0^M y(I)\,dI$$

where $I$ is the irradiation, is attained and all subsequent fuel when discharged has received this irradiation $M$.

This refers to one region alone and the theory has been extended to cover a larger region of the pile over which the rating is not constant. It is seen from this evaluation that the ideal distribution of fuel element irradiation is inversely proportional to the square root of the flux, but this is only a marginal improvement on an operation with a constant irradiation distribution. On the other hand, if the extent of irradiation is allowed to be proportional to the flux, then the maximum irradiation is only $\frac{3}{4}$ of that theoretically obtainable. From this it follows that

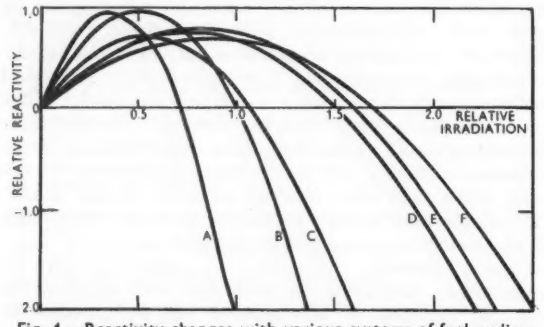



Fig. 4.—Reactivity changes with various systems of fuel cycling normalized at cross-over value to basic point curve. A—bulk channel; B—basic point; C—continuous channel (mean); D—end feed; E—centre feed; F—continuous channel (max.).

a continuous scheme operating with complete channel discharge is most inefficient, while replacement of only the more highly irradiated fuel elements will give considerable improvement in burn-up.

The basic long-term reactivity point curve (i.e. for a single segment in a region of constant flux) can be represented as a simple parabolic form, and using this relationship, reactivity curves against burn-up have been developed for a system in which fuel is fed into the middle of the channel and out at the ends, a system in which fuel is fed into one end of the channel and out the other, and these are compared with a point equilibrium scheme at which it is assumed that all points in a channel are equally accessible for element changing, and an axial inversion system. It follows that the gain of a continuous system of channel discharge over a complete bulk discharge is 1.4 to the crossover point. The point and push-through systems are again an improvement and closely comparable, and with the system of axial inversion a similar gain is obtained. With complete channel discharge, the ratio of maximum to mean irradiation is 1.57, whereas it is only 1.11 with axial inversion (Fig. 4).

The most contentious subject discussed during the Conference concerned the value of "delayed onset" (Fig. 5), where, following start-up of the reactor, no fuel is replaced until after a defined period, followed by a more rapid charge and discharge rate until the long-term equilibrium rate can be introduced. Probably much of the disagreement arose because of a confusion of definitions as to what constituted an "advantage" in the delay, and certainly any purely theoretical evaluation in terms of reactivity only, must needs be modified to accommodate operational convenience and experience. It is also important to keep in mind that, although without delayed onset half the first fuel charge is lost, fuel cycling enables something like $2\frac{1}{2}$ charges to be saved during the life of the reactor.

From the equations developed for the delayed onset theory, it would appear that a gain of something like 13% can be obtained in the irradiation to the crossover point when a region of constant flux is considered. Where a reactor has regions of different flux reaching their equilibrium states at different times, economic advantage may be gained by delaying the commencement of fuel cycling in the regions of higher flux. There is also the point that with delayed onset peak output is approached sooner, although this effect is probably of minor importance. The lower fuel investment also involved may not be material due to the influence of other factors. If the limit to irradiation is a metallurgical limit, then the value of delayed onset is diminished and the whole philosophy of fuel cycling is affected. A factor that it is difficult to take into account at the present time is the possible decrease in metallurgical life following the change of position of a fuel element in a channel, due to change of temperature and flux conditions, and also possible damage during the changing operation. On the other hand, more sophisticated schemes of fuel shuffling may yield dividends and it may even be economic to operate the reactor in such a manner that the overall reactivity against time is represented as a saw-tooth curve. More operational experience, however, is required before the value of such schemes can be usefully assessed.

**Perturbations Due to Fuel Cycles[3]**

Certainly a factor that cannot be ignored is the perturbations of reactor flux and power caused by fuel burn-up and by subsequent fuel cycling. In a clean reactor, due to the negative temperature coefficient, the flux and therefore

the power will be perturbed towards the cool end, but as the concentration of plutonium isotopes builds up, so this trend is reversed and the power curve is perturbed towards the hotter end of the reactor.

Three methods of investigating these and allied effects were discussed. In the first, one group perturbation theory was applied to the calculation of the changes in the axial flux distribution due to the combined effects of xenon poisoning, temperature and Wigner gaps at zero irradiation, and also to the flux changes due to non-uniform fuel irradiation, including the case where the fuel is shuffled axially within the channel. To cover changes occurring in the temperature distribution, an improved method was developed consisting of solving the actual non-linear equations by a process of iteration—the channel being divided into 32 equi-distant sections. Continuous fuelling introduces local channel-to-channel variations of flux, and this problem was treated by an extension of the Feinberg method to include the effect of canning and coolant channels. The methods applied appeared to be powerful and should assist considerably in ironing out local hot spots and in assessing where absorbers should be used and where instrumentation should be fitted to give optimum information.

### Optimization of Fuel Cycles[4]

In the optimization of fuel cycles, useful results can be obtained by less exacting approaches and simple expressions were derived for the limiting burn-up in terms of lattice parameters and enrichment; Fig. 6 shows some of the functional relationships evolved. The treatment considered only the depletion of $U^{235}$, the build-up of plutonium-239 and plutonium-240, other effects such as fission product build-up and $U^{236}$ formation being only of small importance or reaching equilibrium at an early stage in fuel life. The calculations of long-term reactivity changes were based on Hill's equation (*AERE Report* R/R2387), which were then extended to cover a continuous charge/discharge system, the irradiation of fuel elements being assumed to be everywhere the same, and any region containing fuel elements having distributed irradiation times. The simple expression for the fuel burn-up on discharge was derived as

$$x \doteqdot -1.5/(1+M/L)$$

where $x$ is the fractional amount of $U^{235}$ burnt and $M$ and $L$ are simple functions of the lattice parameters. From the expressions linking burn-up with the lattice parameters

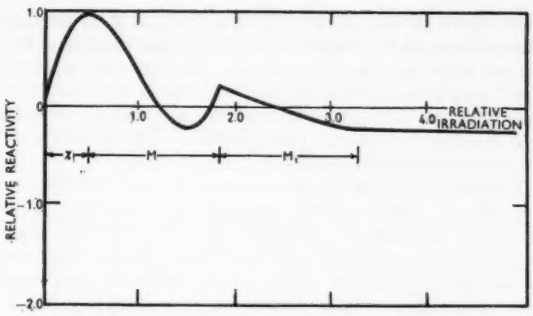



Fig. 5.—Transient reactivity with optimum delayed onset.

it is seen that lattices designed for higher values of $k_\infty$ give lower values of maximum burn-up, so although an increase of $k_\infty$ may permit the reactor to be designed for a higher specific power output, a price may have to be paid in the form of a reduction in fuel life. The downward trend of fuel life with increasing thermal utilization factor, which at first sight may seem surprising, may be understood by reflecting that if the initial value is low, an increase in the absorption cross-section of the fuel, for instance by the accumulation of plutonium-239, will enable an increased proportion of neutrons to be captured in the fuel and will tend to maintain reactivity at a higher value. On the other hand, if the thermal utilization factor is high initially, fuel already captures nearly all the neutrons which are absorbed in the lattice. An interesting result is the effect of variations in $\gamma$ where $\gamma=\varepsilon\,(1-p)$, a high value of gamma implying in general a high value of resonance capture probability. At a given value of $f_0$ the fuel life increases with $\gamma$, as this tends to decrease $k_\infty$ because of the fall in $p$, and so for any given $k_\infty$ it turns out that the best value for $\gamma$ as regards fuel life is always between 0.05 and 0.10. The effects of enrichment also require interpretation. For a given thermal utilization factor, an increase in enrichment produces a marked decrease in burn-up, when it is assumed that the increase in $k_\infty$ which would result from enrichment has been absorbed, for example, in constructional materials; at the same time, the conversion factor drops. If $k_\infty$ is kept constant, enrichment does allow a lower value of the thermal utilization factor to be tolerated, but at higher burn-ups there is a penalty in fuel life. Similarly, although with increasing $\gamma$ fuel life is increased, if $\gamma$ is kept constant an increase of enrichment

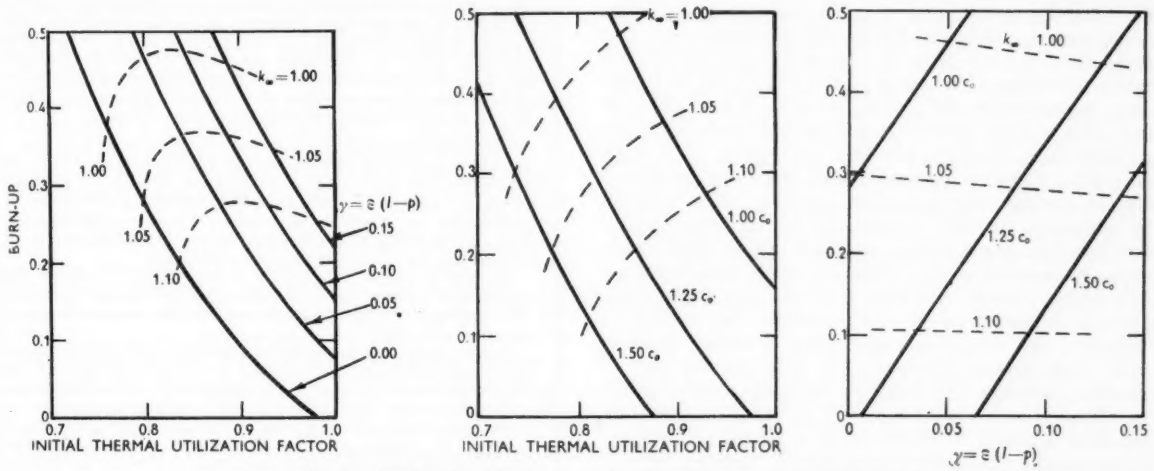



Fig. 6.—Uranium-235 fractional burn-up as a function of various reactor parameters.

has a heavy adverse effect; whereas, if $k_\infty$ is kept constant and enrichment is increased to compensate increases in $\gamma$, the net effect on fuel life is small. An application of this result would be to improve heat transfer in the reactor by increasing the primary surface of the fuel and at the same time keeping the mass of fuel constant. This would lower the resonance escape probability and increase $\gamma$.

The effect of initial excess reactivity on fuel life was also considered. With natural uranium, an increase in the reactivity allocation $\Delta$, that is, the excess of the initial reactivity over the steady state value, can only be obtained by sacrificing reactivity which could otherwise have been used to increase specific power. If, for example, enrichment is used to compensate for stainless steel canning, and the thermal utilization factor is lowered from say 0.9 to 0.8, between 1% and 2% in reactivity must be allocated to the fuel cycle in order to obtain a satisfactory burn-up. In a practical power reactor, between 2% and 3% should be allocated to flux flattening, while larger allocations than this bring diminishing returns. For smaller reactors, much higher allocations must be made to produce the same effect, although the ultimate decision on whether reactivity should be allocated to fuel life or to flattening must be dependent upon the final generation cost, which is not simply a function of core design.

It could be deduced from the figures quoted that it was worth investing ½% in enrichment to obtain 13% better fuel life, although this was, of course, a function of the economics of enriched fuel. It was suggested also, that in practice, only rod diameter and pitch of the lattice were open to significant adjustment and that enrichment should be used to give greater initial reactivity.

**Neutron Economy[5]**

A concept frequently used in discussing optimization is that of neutron economy. There is a temptation to regard neutrons as having an intrinsic value, but this assumption can be a fallacy; the only real criterion must be the ultimate cost of power. An example where neutrons should be absorbed in neither fissile nor fertile material is to give flux flattening and hence an increase in specific power. Nevertheless, although the concept has its dangers, the conclusion was drawn that it could be useful in giving an approximate evaluation of the effect of changing the parameters.

Returning, however, to the question of enrichment, some assessment of its potential advantages can be obtained by basing costs on U.S. prices of $UF_6$ (Fig. 7). When the necessary allowances are made for fabrication costs, investment in each ton of fuel in the reactor increases with enrichment, but it may be possible to increase specific fuel rating more than is required to offset this, and so reduce fuel investment per kW. This, however, has no effect on the value of fuel invested in the ancillary processes such as fabrication, cooling, chemical processing. The most powerful method of reducing overall investment is increasing the burn-up. Consideration, however, must be given to additional ancillary charges arising from the use of enriched fuel, for example, increased cost of fabrication, increased number of fuel element components necessary with higher ratings, and also increased processing costs. Changes in the price of raw materials also cannot be neglected, and while the market price of natural uranium could drop, this would have little effect on the cost of enriched uranium. In practice also, as stated before, metallurgical considerations are likely to be paramount, and there is likely, therefore, to be an excess of reactivity which could be used to increase specific output. Even if there were no metallurgical limit, it is possible that some reactivity should be invested in rating at the expense of fuel life, although these considerations must be dependent on the importance of capital costs in relation to fuel costs.

**Operational Problems[6]**

Only at the end of the Conference was time made available for a discussion on the operational problems associated with fuel cycling. In other engineering fields one usually found that where plant was of very high capital cost, operational methods were highly organized and could be based on past experience, and in those industries accustomed to rapidly advancing technologies, as for example the oil industry, capital costs tended to be lower and plant could be considered obsolete at a fairly early stage. In the nuclear industry, capital costs were high and technologies were advancing rapidly, operation was, therefore, bound to be of an evolutionary nature and conservative in outlook. When the first stations for the CEGB come on load, considerable experience will have

Cycles de Combustible Nucléaire

*Lors d'un symposium organisé par l' "Institute of Physics" en association avec la B.N.E.C., qui s'est tenu les 22 et 23 Janvier, des discussions eurent lieu sur les avantages possibles du cyclage du combustible dans un réacteur refroidi au gaz et modéré au graphite. La Conférence a été principalement une évaluation théorique en termes de considérations de réactivité.*

*Lorsque la réactivité est le facteur principal, le cyclage du combustible permet d'obtenir des gains considérables de brûlage par comparaison au simple chargement-déchargement en gros d'une région.*

*Suffisamment de temps fut donné pour une courte discussion des problèmes de fonctionnement impliqués par les divers systèmes de cyclage de combustible qui furent l'objet d'une analyse. On a reconnu que les considérations métallurgiques peuvent présenter une importance primordiale dès le début, et que même avec les perfectionnements des techniques de fabrication d'éléments, les considérations de fonctionnement peuvent exiger un déchargement avant le moment que les valeurs de réactivité théoriques pourraient indiquer.*

Umlauf des Kernkraft-Brennstoffs.

*Bei einem Symposium, das vom Institute of Physics gemeinsam mit dem B.N.E.C. organisiert war und am 22. und 23. Januar stattfand, wurden die möglichen Vorteile eines Umlaufs des Brennstoffs in einem gas-gekühlten Reaktor mit Graphit als Moderator diskutiert. Die Konferenz kam in der Hauptsache zu einer theoretischen zahlenmässigen Bewertung in Berücksichtigung der Reaktivitäts-Bedingungen.*

*Wenn Reaktivität der massgebende Faktor ist, dann bringt der Umlauf des Brennstoffes einen beträchtlichen Gewinn im Verbrauch durch Verbrennen gegenüber dem einfachen Einfüllen und Entfernen der Elemente im Ganzen in einem Abschnitt.*

*Die Zeit reichte für eine kurze Diskussion der Betriebsprobleme, die bei den verschiedenen Systemen eines Brennstoff-Umlaufs auftauchen, die analysiert wurden. Es wurde anerkannt, dass metallurgische Ueberlegungen wahrscheinlich zuallererst kommen, und dass selbst mit Rücksicht auf Fortschritte in der Technik der Herstellung von Elementen Betriebsbedingungen die Entfernung verlangen könnten, bevor die theoretisch gefundenen Werte für die Reaktivität dies angezeigt erscheinen liessen.*

Ciclos de Combustible Nuclear

*En una Conferencia organizada por el Instituto de Física en asociación con la B.N.E.C., celebrada en los días 22 y 23 de enero, se discutieron las potenciales ventajas del ciclado de combustible en un reactor moderado con grafito y enfriado por gas. Mayormente la Conferencia era una avaluación teórica en términos de las consideraciones de reactividad.*

*Cuando el factor principal es la reactividad, el ciclado del combustible permite que se obtenga una considerable ganancia en "quemado" comparado con una sencilla carga-descarga a granel de una región.*

*Se dió tiempo para una breve discusión con respecto a los problemas operacionales implicados en los diversos sistemas de ciclado de combustible que fueron analizados. Se reconoció que es probable que las consideraciones metalúrgicas sean de primordial importancia al principio y que aun con mejoras en las técnicas de fabricación de elementos, las consideraciones operacionales puede que exijan descarga antes de que los valores teóricos de reactividad lo indicarían.*

been built up on Calder and Chapelcross, but there will still be no really valid experience on fuel element behaviour. Accelerated tests can be made on irradiation damage, of steel for example, but fuel life tests cannot be accelerated. The most important aspects of operation will, therefore, be associated with uncertainties in fuel element behaviour and burn-up.

It was as well when considering the introduction of highly sophisticated schemes to bear in mind that a 20% change in fuel life was only reflected by a change of 5% in power cost; nevertheless, several million pounds could still be involved. By the time Berkeley and Bradwell become operational, uncertainties concerning reactivity should have been evaluated and metallurgical considerations will, therefore, be uppermost. It is conceivable that, with advancing techniques, calculations could show that some spiking would be economic to give the maximum metallurgical performance and, should this appear to be the case, enriched fuel would be made available. It would be unwise to lay down at this stage a rigid scheme of fuel cycling and also of pile flattening as this last can be adjusted as a result of experience, and it is clearly desirable to take advantage of any metallurgical advances.

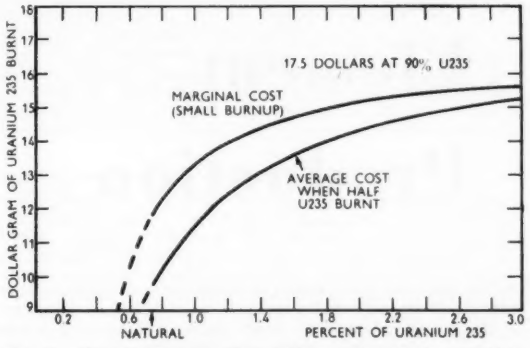

DOLLAR GRAM OF URANIUM 235 BURNT
17.5 DOLLARS AT 90% U235
MARGINAL COST (SMALL BURNUP)
AVERAGE COST WHEN HALF U235 BURNT
NATURAL
PERCENT OF URANIUM 235

Fig. 7.—Raw fuel costs of burning uranium-235, excluding fabrication, reprocessing, plutonium credit, etc.

In the discussions, particularly on delayed onset, bringing the reactor to equilibrium had been regarded as the major problem, but the finite life of the reactor must be taken into account and consideration also given, therefore to the cycling of fuel in relation to the end of the reactor's life.

The assumption had been made in calculations presented at the symposium that the circuit was clean, but, should a really bad burst occur, it is possible that the channel concerned would have to be discharged and not recharged. It may be preferable to discharge earlier than calculations would indicate desirable, in order to minimize this chance. In this type of context, it was not the mean fuel element life that was of such importance, but the tail of the life curve, and the possibility of a few bursts in many thousands of fuel elements can seriously affect charge philosophy.

Improvements in fuel elements will not merely affect the relative significance of metallurgical limitations and reactivity limitations. Marginal improvements in life would be accommodated operationally relatively easily, but should significant improvements be made, which allow a higher temperature, then a major operational problem is involved in taking advantage of this. When certain channels are first loaded with the new element, the remainder of the reactor being fuelled with the old element, the coolant flow round the new elements must be adjusted to take advantage of the new limits. As more of the reactor is loaded with the new element, however, these flows must be adjusted progressively back to the initial ratios.

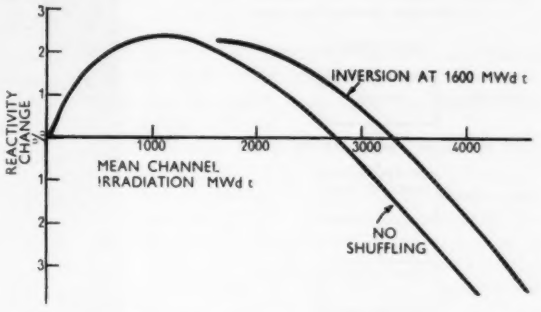



Fig. 8.—Reactivity gain in Hunterston reactor as a result of axial inversion compared with complete channel change.

Pre-planning of fuel cycling is, nevertheless, important because of the out-of-pile facilities necessary to handle irradiated fuel elements. Processing plants take two to four years to build and these must be available at a time when the fuel has finished its cooling period. Similarly, fuel element fabrication plant must be geared to provide the type and number of fuel elements necessary to feed the various reactors. Under-production would result in reactors having to run at reduced power and over-production would cost money. Fabrication, therefore, must also be geared to the fuel cycle.

### Viewpoint of Generating Authorities

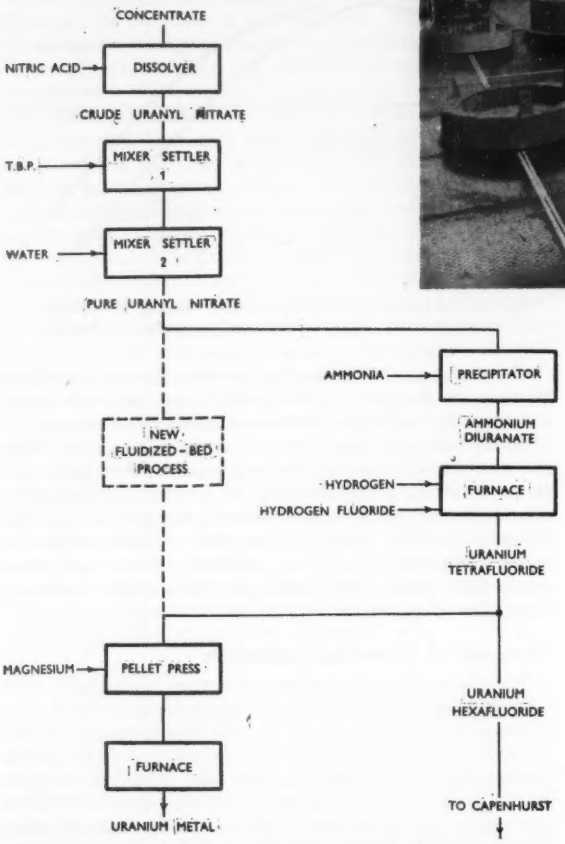
The Generating Authorities' operating philosophy must be based on electricity supply considerations. It is vital to keep a reactor running; the loss, for example, of one reactor from either Bradwell or Berkeley would cost the Generating Board £8,000 per day, and should a complete discharge of a core be necessary, the estimated loss well in the region of £1 million. An overriding consideration, therefore, is that the possibility of shut-down must be kept to a minimum. In the early days of the reactor life, there was bound to be a certain amount of operational experimentation and one of the arguments against delayed onset is the necessity for becoming accustomed to the charge-discharge operation at an early stage in the reactor life. A further argument is that, with delayed onset, a higher rate of discharge is required just at a time when there is the greatest possibility of fuel element failure, i.e. when a greater number of fuel elements are reaching the end of their metallurgical life, and this may result in the charge-discharge facilities being overloaded. A simple fuel cycle would be adopted on the first charge, whilst information was being collected, and to give greater confidence to the operating staff. Clearly it was important to collect as much data on fuel element behaviour as possible, and an intensive programme is required which will allow elements to be examined at all levels of irradiation and before they burst. Detailed examination of burst elements is, of course, necessary, but the pre-burst behaviour should not be neglected.

#### SYMPOSIUM PAPERS

1. Rose, H., and Syrrett, J. J. "Long Term Reactivity Changes."
2. Lewis, S. E. "Theory of Once-through Fuel Cycles."
3. Balfour, J. G., Booth, D. L., Bulloch, R. S. "Perturbations Due to Fuel Cycles."
4. French, P. R. J., and Lowthian, C. S. "Optimization of Fuel Cycles (1)."
5. Grant, P. J., Oswald, W., Russell, P. D. D. "Optimization of Fuel Cycles (2)."
6. Stewart, J. C. C., and Franklin, N. L. "Operational Problems Associated with Fuel Cycling."

(Right) Magnesium reduction of uranium tetrafluoride to uranium metal is carried on in these furnaces.

(Below) Simplified flow diagram of the uranium processing plant.




# Fuel Element Production

**In just over ten years almost a million bars of uranium have been produced at the AEA's Springfields establishment. Because of the growing demand for fuel elements a new plant will shortly come into operation.**

THE uranium processing plant at Springfields was established by the Ministry of Supply as long ago as 1946, when the foundations of the U.K. nuclear energy industry were laid. In order to save time and conserve effort, an existing wartime works between Blackpool and Preston was taken over. The first uranium rods were produced in October, 1948, some two years after the atomic energy project had been initiated. The original process was planned to work from crude ore (pitchblende), as supplies of concentrate (uranium oxide) did not begin until August, 1954.

While having many advantages, the use of an existing factory imposed limitations on plant layout—it was practically impossible to obtain an ideal flow line for production. Nevertheless, in addition to an impressive production of uranium—approaching 1,000,000 bars—the original factory has provided valuable information for planning a new plant, part of which is already in operation. Some idea of the care devoted to the design can be gathered by the elimination of personal breathing apparatus in the new plant—nowhere is it necessary to use respirators in normal circumstances.

When the new factory is complete, the entire process from concentrate to finished rods will be in one straight line, with an access corridor running the whole length giving entry to the various departments. At present it is necessary to pass the material (at a liquid stage) back to the old plant, as shown in the simplified flow diagram.

## Uranium Production

The processing of uranium concentrate has been previously described, but in order to appreciate the description of the plant it may be convenient to review it briefly here.

The concentrate, a crude oxide containing some 60-70% uranium, arrives in steel drums which are first sampled as required by a mechanical "thief." The scope of sampling depends on the conditions of the contract for the particular source of supply. With some batches every drum is sampled; with others as few as one in ten. Canadian concentrate is a bright yellow powder; Australian is a medium buff colour and considerably coarser (about $\frac{1}{8}$ in.), South African is almost dark brown and crushed to about $\frac{1}{4}$-$\frac{1}{8}$ in.

The drum containers are mechanically tipped in enclosed cubicles; from the hopper a screw feeder conveys the material to a stainless steel dissolver, with steam heating coils and mechanical stirrers, where the nitric acid reaction takes place. The solution is fed from the dissolvers to rotary filters, each with a horizontal drum of stainless steel gauze with a coating of silica, which is partially submerged in the solution. Vacuum applied to the interior of the drum assists the solution to pass through, leaving the residue on the outside of the drum where it is wetted with water sprays and scraped off by a knife edge similar to the "doctor" blade used in photogravure printing. This material is afterwards mixed with water and re-filtered.

The solution of impure uranyl nitrate then passes for

La Production des Eléments Combustibles

*L'installation de traitement d'uranium à Springfields, près de Preston, Angleterre, fonctionne maintenant à plein rendement depuis plus de 10 ans. Bien qu'au début elle ait été conçue pour la marche à la pechblende, l'installation emploie du concentré d'oxyde d'uranium depuis Août 1954. L'équipement de traitement actuel se conforme à un modèle traditionnel, le concentré étant converti en tétrachlorure, lequel est par la suite réduit en métal, purifié et ensuite coulé en barres. Jusqu'à maintenant, environ un million de barres d'uranium ont été produites à Springfields. Ensuite, ces barres sont mises en boîtes, les éléments en résultant étant fournis tant à Calder Hall qu'à Chapel Cross.*

*Afin d'augmenter la fourniture d'éléments combustibles pour faire face au développement du programme d'énergie nucléaire de la Grande-Bretagne, la nouvelle méthode de production utilisant le procédé de "couche fluidisée" entrera en fonctionnement sous peu à Springfields.*

Die Herstellung von Brennstoff-Elementen.

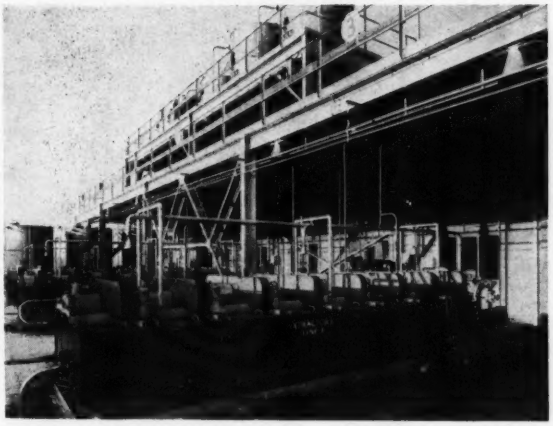
*Das Werk in Springfields bei Preston zur Verwertung von Uran ist jetzt über 10 Jahre in vollem Betrieb. Obwohl ursprünglich geplant zur Behandlung von Pechblende, so ist doch seit August 1954 ein Konzentrat von Uranoxyd benutzt worden. Die Ausrüstung für die Behandlung, wie sie dort besteht, ist konventionell, das Konzentrat wird in Tetrachlorid verwandelt, dann folgt die Reduktion zum Metall, die Läuterung und das Vergiessen zu Stangen. Bis jetzt sind rund eine Million Stangen Uran in Springfields hergestellt worden. Diese Stangen werden mit Mänteln versehen, und die fertigen Elemente dann nach Calder Hall und Chapel Cross geliefert.*

*Um die Lieferung von Brennstoff-Elementen zu verstärken und mit Englands immer grösser werdenden Programm zur Verwertung der Kernkraft Schritt zu halten, wird demnächst das neue Herstellungs-verfahren, das Schwebeverfahren (fluidized bed process) benutzt, in Springfields in Betrieb genommen werden.*

Producción de Elementos de Combustible

*La instalación de procesado de uranio en Springfields, cerca de Preston, ha estado ya en pleno funcionamiento durante más de 10 años. Aunque incialmente diseñada para trabajar a base de "pechblende," la instalación ha estado usando concentrado de óxido de uranio desde agosto de 1954. El equipo de procesado existente sigue un modelo convencional, convirtiéndose el concentrado en tetracloruro, el que se reduce subsecuentemente a metal, purificándose y luego fundiéndose en varillas. Hasta la fecha se han producido aproximadamente un millón de barras de uranio en Springfields. Estas barras han sido subsecuentemente envasadas, suministrándose los elementos resultantes tanto a Calder Hall como a Chapel Cross.*

*Para suministrar es la bastecimiento de elementos de combustible para la mayor parte del expansivo programa nuclear de la Gran Bretaña, el nuevo método de producción, empleando el procedimiento de "lecho fluidizado" comenzará a funcionar dentro de breve en Springfields.*



During the solvent extraction process carried out in these fully automatic mixer settlers, uranyl nitrate is removed from other dissolved impurities.

purification to a 2-stage solvent extraction process, using 20% tributyl phosphate in odourless kerosene in 16-stage mixer-settler units.

**$UF_4$ Production**

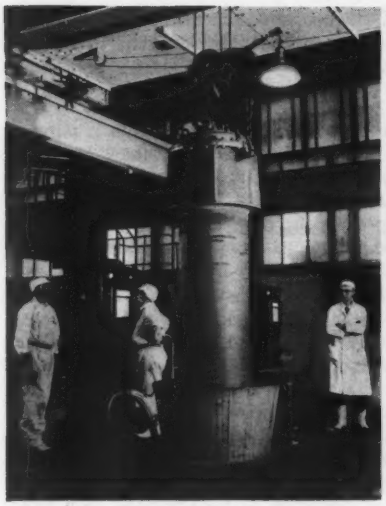
At this point the pure uranyl nitrate solution is pumped back into the old plant to be treated by the "Dryway" process. When the new plant is complete a fluidized-bed process will be used.

In the Dryway process the uranyl nitrate is treated with ammonia in a precipitator, to form ammonium diuranate. After washing, this is discharged into Nutsch filters as a slurry. The resulting yellow paste is then loaded into graphite trays which have holes either in the centre or at the periphery. These are stacked alternately to make a column of trays with a free passage for gas, covering the whole area of all the trays. The stacks are loaded into furnaces and first hydrogen and then anhydrous hydrofluoric acid are passed through. This produces uranium tetrafluoride which, after cooling, is passed back to the new plant as a light green powder. A certain amount of the tetrafluoride is converted to hexafluoride and transported in steel tanks to Capenhurst for the production of enriched uranium.

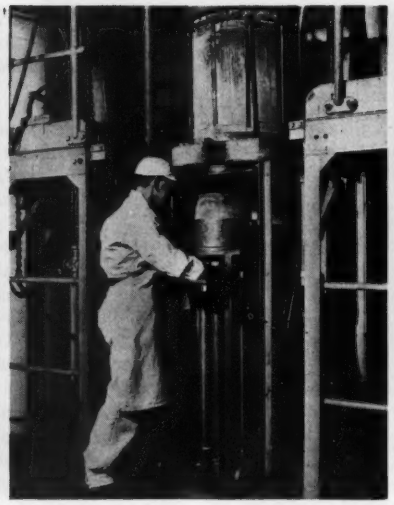
The cooling bay where reactors are cooled after the chemical reaction in which magnesium combines with fluorine, and uranium is reduced to metal in the form of a billet.

**Reduction**

The tetrafluoride is passed back to the appropriate section of the new plant for reduction to metal. It is automatically weighed and mixed with the appropriate amount of magnesium chippings, and the mixture is fed to a press which produces cylindrical pellets each weighing some 10 kg. Sufficient pellets to produce a 200 kg billet of uranium (21) are arranged in seven 3-high stacks around the periphery of a crucible. The crucible has a graphite lining built up in sectors with a stepped formation so that the lower portion forms a sump about two-thirds of the diameter of the remainder. The pellets are stacked on the shelf around the top of the sump. The crucible is contained in a steel reactor which is placed in an electric furnace and evacuated. The melting of the pellets and the consequent exchange reaction produces pure uranium, which is recovered as a cylindrical billet, with a lump of slag on the top. After fettling, the remaining surface slag is removed from the billet by cooking first in ammonium chloride, then in nitric acid. Final traces of impurity are removed from the metal by subjecting the billet to a vapour blast. The uranium is then passed to the billet store.



Removing a reactor from the furnace. Uranium is recovered in billet form.



Mould for Calder Hall rods being placed in a vacuum casting furnace.

When loaded with uranium rod the fuel element cans are checked for leaks.

**Rod Production**

First step in production of uranium rods is the remelting of the billet and the casting of the rods in rough form.

Moulds of steel with a graphite lining are assembled, in numbers according to their length, on a bogie and a header system is fitted. The furnace portion consists of a graphite crucible: a bottom tap-hole is closed by a rising plug that can be externally operated to release the charge. The heating coil, operating at about 1,650 c/s, surrounds the charge which is made up to 500 kg with billets and remnants, such as runners and risers from previous casts. The entire assembly is covered with a vacuum bell and then is charge melted and tapped, filling all the moulds simultaneously. After cooling, the mould assembly is dismantled and the rods sent to a bond store, each cast being kept separate.

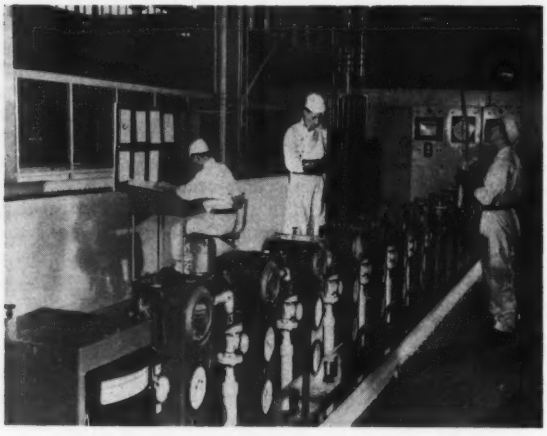
**Machining**

The machining portion of the process has been largely mechanized and most of the transporting between machines is done by conveyor systems. Machining methods follow conventional practice, but in all cases exhaust ventilation prevents particles passing into the atmosphere. There is also an ample supply of coolant at the cutting head to prevent ignition of swarf or, at least, to minimize the risk. As uranium work-hardens easily, it is necessary to take heavy cuts. All the machines seen were of massive construction. According to Nichols†, power requirements may be 50% greater than for the machining of an equivalent steel rod.

First operation on the cast rod is one of straightening and cleaning. It then passes on to a machine resembling a twin lathe with two sets of headstocks which face up both ends so that the rod is slightly above the specified length: a groove cut near one end facilitates suspension in future operations. The machine also stamps an identification number on the lower end of the rod.

Heat-treatment follows in the form of a beta-quench

† "Uranium and its Alloys," R. W. Nichols, *Nuclear Engineering*, September, 1957, p. 355.



To reduce the grain size of the uranium metal, bars are heat treated. (Above) Alpha-annealing equipment.

A further stage in heat treatment involves the use of this beta-quench apparatus.

operation to reduce grain size and give random orientation, thus minimizing distortion under operating conditions. In this operation the bar is fed vertically by means of motor-driven rollers, at a controlled speed through an induction heating coil operating at about 10 kc/s into a water tank below.

The second heat treatment is an alpha-annealing operation. For this the rods are suspended in groups in containers which are evacuated and filled with argon, then placed in a furnace. The heating is followed by controlled cooling.

After the annealing operation, the bars are straightened and then machined to limits of plus or minus 0.001 in. in a centreless turning machine. This has cutters rotating concentrically about the bar which moves horizontally through them. The cut is about 0.04 in. The final operation is the cutting of several anti-ratcheting grooves at regular intervals along the bar, into which the can will eventually be keyed, to prevent ratcheting following differential expansion of the bar and can.

Fuel rod machining line. One machine straightens and cleans the rod; the other cuts, grooves and stamps each section with a number.

**Canning**

The new canning line is not yet in operation, but Calder-type elements were seen in the older portion of the plant. As is generally known, there are two types of element, one having concentric fins machined from the solid, and the other, although similar in general appearance, being provided with rolled fins following a fine-pitch helical path. So far as could be ascertained, the canning operation is similar for both types, except for the final operation of fitting the bracing struts.

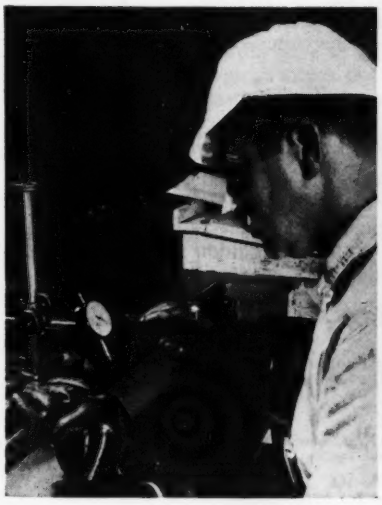
The two ends of the cans receive different treatments. No. 1 end is first provided with a cap and spacer, the cap fitting over the end of the can. This is welded into position by an argonarc welding head which is automatically traversed around the weld.

No. 2 end has an internal thread for a screwed plug with a conical end, the tube end being machined out to provide a bevelled seating around the screwed hole. Final machining of this seating is carried out *after* the uranium rod has been placed in position, as the tolerances on the length of both rod and can could, if opposed (i.e., with a rod near the maximum and a can near the minimum length) produce interference between the rod and the screwed end of the plug before the conical portion was hard down on the seating. The plug has two blind holes for a pin-spanner in its upper surface.

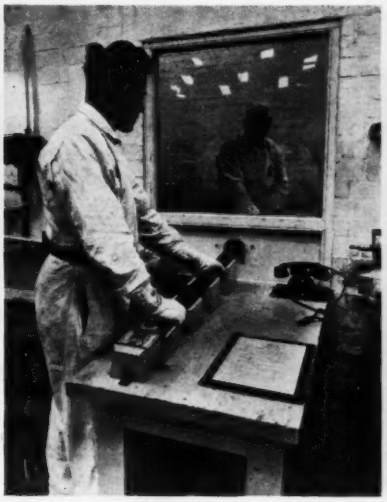
When the length has been corrected, the assembly is placed, open end upwards, in a fixture, and the plug placed in position but not screwed down. A vacuum head, containing a rotary pin spanner is clamped to the end of the can seating on the outside edge of the can end with an O-ring gasket interposed. The can is then evacuated and, by means of a measuring valve, 1 cc of helium is allowed to enter, after which the plug is screwed down hard enough to make a temporary gas-tight seal until the end can be welded. The completed can is externally pressurized to force it into the anti-ratcheting grooves.

Tests carried out on completed cans include full X-ray photographs of both welds (three pictures to each weld) and leak testing. This is carried out by placing the cans under vacuum, and testing for helium with a mass spectrometer which is capable of detecting 1 part in 200,000.

Cleaning of the completed can follows in a 1½% citric acid solution with rotary nylon brushes. End fittings and longitudinal bracing struts are added and the can is

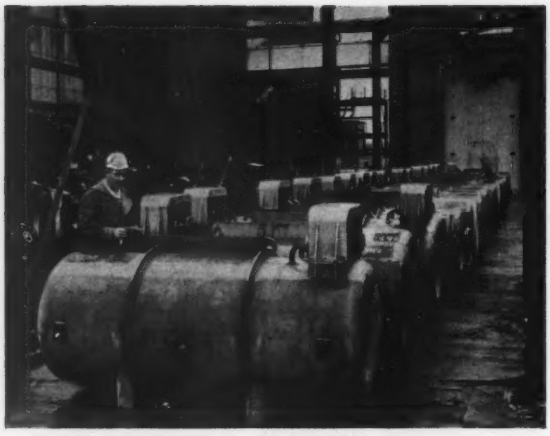


After machining, the straightness of the rod is checked.



Canning a Calder fuel element.

Before packing, each fuel element is thoroughly cleaned.



Hex bottles awaiting filling outside the fluorination plant. When filled the vessels are transported to the gaseous diffusion plant at Capenhurst.

complete. The struts, which are spot-welded around the element, differ for the two types of can. For the concentric fin type of can the strut unit is supplied partly assembled in two portions, which are placed in position and spot-welded together. It is considered that with the rolled fins the same degree of accuracy cannot be obtained, and that if the strut unit could not be adjusted, distortion of the fins would result. The struts are, therefore, supplied in six pieces which are spot-welded together while in position.

### The New Production Lines

The new canning line is laid out on true flow line principles. After degreasing, washing and drying as before, the can is placed in a horizontal fixture. One of the features of the new process is that all operations are carried out with the can horizontal. As with the original process, the uranium is kept in a separate room until placed in the can through a port in the wall. The uranium in this case is pushed into the can before the first end is welded into position and the fixtures are arranged so that, for the welding operation, the can revolves instead of the electrode moving around the circumference of the weld. Otherwise the process appears substantially the same.

Detailed exceptions are the squeezing of the can into the anti-ratcheting grooves, which is done under an hydraulic pressure of 10,000 p.s.i., X-ray examination which is arranged so that the photographic process utilizes a continuous roll of film, and the final cleaning of the can, which is carried out by ultrasonic methods in place of the scratch brushing of the old process.

No exact figures are available, but it has been stated that the sale price of the complete elements is £22,000 per ton.

In the control room flow diagrams are extensively used. The panels shown here deal with extraction purification and blending.

**Gas-lubricated Bearings Translations** (*see facing page*).

Les Paliers Lubrifiés au Gaz en Technique Nucléaire 2ème Partie
*Le palier hydrostatique exige une source de gaz à haute pression qui est alimenté dans le palier par une résistance. Le palier lui-même fournit une autre résistance et les propriétés de transport de charge sont déterminées par les valeurs de ces résistances et par la pression du gaz.*

*Les paliers peuvent se classifier en paliers simples, à orifice, à orifice annulaire, capillaires et poreux. Chacun de ces types fait l'objet d'une discussion détaillée en ce qui concerne le coussinet, et on donne des comparaisons des pressions et charges de pompage requises pour le maintien d'une force déterminée. Les techniques de conception et de fabrication sont décrites et une section en conclusion traite des conditions équivalentes dans les paliers de butée.*

Gas-geschmierte Lager in Konstruktionen zur Kernkraft Verwertung. Teil 2.
*Das hydrostatische Lager verlangt Hochdruck-Gas, das in das Lager über einen Widerstand eingeleitet wird. Das Lager selbst dient als weiterer widerstand, und seine Eigenschaften unter Last sind bestimmt durch die Werte dieser Widerstände und durch den Gasdruck.*

*Die Lager können nach folgender Klassifizierung unterteilt werden: Mit einfachem Einlass, mit ringförmigem Einlass, kappilar und porös. Jede dieser Typen wird im Einzelnen im Hinblick auf ein Gleitlager diskutiert, und die erforderlichen Drücke und Belastungen der Pumpen verglichen, um eine gegebene Leistung aufrechtzuerhalten. Die Konstruktion und die Fabrikationstechnik werden beschrieben, ein Schlussabschnitt bespricht gleichartige Bedingungen für Drucklager.*

Cojinetes Lubrificados con Gas en la Ingenieria Nuclear 2a Parte
*El cojinete hidrostático exije una fuente de gas a alta presión e que se alimenta dentro del cojinete mediante una resistencia. El cojinete mismo provee otra resistencia y las propiedades portadoras de carga son determinados por los valores de estas resistencias y por la presión de gas.*

*Los cojinetes pueden ser clasificados como sencillos, de orificio, de orificio anular, capilares y porosos. Se discute cada uno de estos tipos en detalle para el cojinete de muñón y se hacen comparaciones de las presiones y de la carga de bombeo necesarias para mantener una fuerza determinada. Se describen el diseño y las técnicas de fabricación, y una sección final trata de las condiciones equivalentes en los cojinetes de empuje.*

### Staff

In the operating and production departments of the works there are some 2,750 employees, of whom about 80% are industrial staff and of the other 20%, the majority are scientific, engineering and technical personnel. The remainder are engaged on administrative, clerical, stores and drawing office duties. In addition there is also a large research and development section.

## SPRINGFIELDS—MAIN CONTRACTORS

**Civil Engineering**
SIR A. McALPINE, LTD., Hooton, Cheshire.
R. M. DOUGLAS, LTD., Birmingham.
BROWN AND JACKSON, LTD., Fleetwood.

**Structural Steel**
T. SIDEBRIDGE, LTD., Middlesbrough.
R. WATSON, LTD., Bolton.

**Mechanical Instruments**
MITCHELL ENGINEERING, LTD., London.
T. W. WARD AND CO., LTD., Sheffield.

**Electrical Work**
JAMES SCOTT, LTD., Glasgow.

# Gas-Lubricated Bearings in Nuclear Engineering—Part II

By D. PANTALL, A.M.I.Mech.E. and C. H. ROBINSON

This, the second article on gas bearings, deals with hydrostatic (pressurized) types beginning with an analysis of the important features of plain journals and concluding with a section on thrust bearings.

IN a pressurized gas bearing, gas flows from a high pressure source to a lower ambient pressure through two flow resistances in series. One of these resistances is formed by the clearance space between the bearing members. The other lies in the circuit between the high pressure source and the bearing proper, and is called the "External Resistance," although in most practical cases the resistance is formed within one of the bearing members.

A simple journal bearing is illustrated in Fig. 1. It has two feed holes, which are diametrically opposed, and equally spaced from the ends of the bearing shell. The gas flows through external restrictors $R_{ex}$, and thence between the bearing members to discharge at the ambient pressure $P_a$. If the shaft and sleeve are concentric, there is an equal resistance to flow through the two feed holes, and there is the same flow and pressure loss in each of the external resistances. The pressure distribution within the bearing space is the same about each of the feed holes, and no gas force acts on the shaft. If the concentric position is a stable one there can be no externally applied load on the shaft. If such a load is applied, the shaft is displaced relative to the shell, say towards feed hole 2 of Fig. 1b. The flow through this feed hole is immediately reduced, since the decreased clearance increases the resistance to gas flow. The reduced flow through the external resistance associated with feed hole 2 gives rise to a smaller pressure drop in $R_{ex2}$, and, as the supply pressure $P_s$ is constant, the pressure at feed hole 2 rises. Conversely, the pressure at feed hole 1 drops and a gas pressure difference is built up across the shaft, in opposition to the applied load, and the system attains a stable eccentric position if the load is within the bearing's capacity. The greater the value of the supply pressure the stronger the bearing, and, for a given supply pressure, the greater the load the greater is the shaft displacement needed to balance it.

In liquid hydrostatic bearings the feed holes terminate in large pockets extending over much of the bearing area, increasing the area over which the feed hole pressures are experienced. If a gas bearing is constructed in the same manner the relatively slow pressure changes in the pockets (the gas being compressible) give rise to a hunting phenomena; for this reason any pockets used in gas bearings must be of very small volume, and serve to smooth out the flow path rather than to increase the area over which the feed hole pressure is experienced.

### Types of External Restrictor

The form of the external resistance provides a convenient classification of the various types of hydrostatic gas bearing.

(1) *The Simple Orifice* (Fig. 2), in which the pressure losses are due to aerodynamic forces. The flow path is reduced in area immediately prior to the entry to the

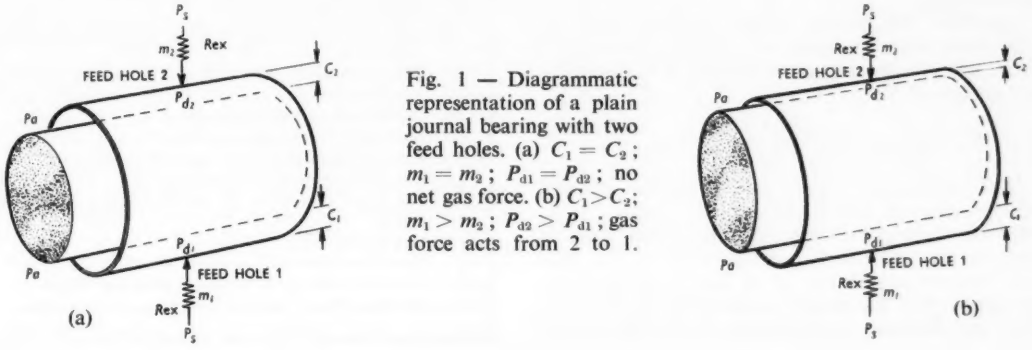



Fig. 1 — Diagrammatic representation of a plain journal bearing with two feed holes. (a) $C_1 = C_2$; $m_1 = m_2$; $P_{d1} = P_{d2}$; no net gas force. (b) $C_1 > C_2$; $m_1 > m_2$; $P_{d2} > P_{d1}$; gas force acts from 2 to 1.

M

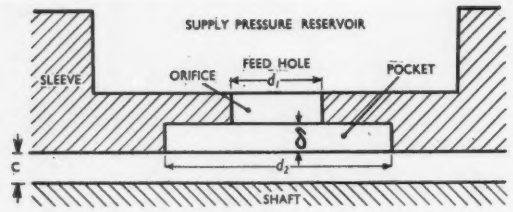



Fig. 2.—Simple Orifice; orifice area ($\pi d_1^2/4$, is less than escape areas to pocket ($\pi d_1\ (c + \delta)$) and to bearing clearance ($\pi d_2 c$).

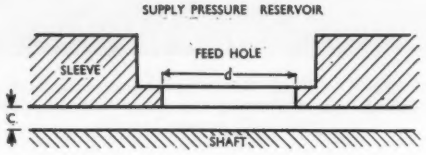



Fig. 3.—Annular Orifice; no pocket is provided and feed hole area ($\pi d^2/4$) is greater than bearing clearance escape area ($\pi dc$).

clearance space, and the gas is accelerated in passing through the reduced area. To ensure that the orifice is, in fact, the smallest area the exit from the feed hole is flared, or terminated in a shallow pocket.

(2) *The Annular Orifice* type of external restriction is obtained if the pocket or flaring is omitted (Fig. 3). Here the pressure loss is again due to aerodynamic forces as the gas is accelerated to pass through the area formed by the feed hole circumference and the clearance. The two types differ in that the area of the simple orifice does not vary while that of the annular orifice changes with variations of the local clearance.

(3) *The Capillary Bearing* relies upon viscous forces to reduce the pressure, the gas being fed through lengths of narrow bore tubing situated between the bearing and the high pressure source.

(4) *The Porous Bearing* differs markedly from the other three in that the gas is admitted through a porous matrix forming one of the bearing members, rather than through a number of separate feed holes. The gas pressure losses are due to viscous forces.

## JOURNAL BEARINGS

### Design Parameters

The load that the bearing carries depends upon the supply pressure and the area over which the pressure differential acts. These terms are combined in a dimensionless load coefficient:

$$C_L = \frac{\text{Load}}{\text{Bearing Plan Area} \times (P_s - P_a)}$$

The load coefficient is also affected by the ratio of $R_{ex}$ and the resistance within the clearance space. If $R_{ex}$ is small, the feed hole pressures, when the shaft is unloaded are very close to $P_s$; displacement of the shaft alters the pressure only in the arc of increasing clearance. If $R_{ex}$ is large, then the major pressure change is in the arc where the clearance is decreasing; at an intermediate value the pressure changes in both arcs and the bearing has greater strength.

The nature of the pressure loss in simple or annular orifice types of bearing precludes the use of a geometric ratio to define this resistance ratio, principally because the pressure drop in the orifice does not vary simply with the flow through it, but also because the mass flow through the orifice becomes constant when the pressure ratio across the orifice is greater than the critical pressure ratio. However, a pressure ratio

$$K_g = (P_d - P_a)/(P_s - P_a)$$

where $P_d$ is the pressure at the feed holes when the shaft is unloaded, can be shown[1] to fulfil this requirement adequately. A method of deriving $K_g$ from the gas parameters and the bearing geometry is discussed later. A simple geometric function could be used for a bearing with capillary compensation, nevertheless it is convenient to use the parameter $K_g$ for this class of bearing also.

It is not possible to define a unique downstream pressure ($P_d$) for a porous journal bearing where the gas is admitted over the whole of the bearing area. In consequence a pressure ratio cannot be used to represent the ratio of the bearing flow resistances. A dimensionless group fulfilling this requirement,[2] is:—

$$\lambda l = l \sqrt{\frac{24\alpha}{Dc^3 \log_e (r_o/r_i)}}$$

### Factors Affecting Strength

*Feed Hole Number and Spacing.* Bearings fed through separate feed holes are influenced by the number and position of the feed holes. In practice a bearing would have considerably more than the two feed holes of the bearing illustrated in Fig. 1, and these might be disposed in one or two rings.

If the bearing has two rings of feed holes, then the pressure in the space between the rings tends to the $P_d$ of

**NOMENCLATURE**

| | |
|---|---|
| $C_L$ | Load coefficient—dimensionless. |
| $d$ | Feed hole diameter—in. $\times 10^{-3}$ |
| $D$ | Shaft diameter—in. |
| $c$ | Clearance (radial)—in. $\times 10^{-4}$ |
| $K$ | Ratio of absolute pressures across feed holes—dimensionless. |
| $K_g$ | Ratio of "gauge pressures" across feed holes—dimensionless. |
| $K_T$ | Ratio of supply to exhaust pressure—dimensionless. |
| $l$ | Half length of porous bearing; axial distance from feed hole to end of bearing shell—in. |
| $P_a$ | Ambient (exhaust) pressure—p.s.i.a. |
| $P_d$ | Pressure at throat of feed hole—p.s.i.a. |
| $P_s$ | Supply pressure—p.s.i.a. |
| $r_i$ | Inner radius of porous bearing; pocket radius of thrust plate—in. |
| $r_o$ | Outer radius of porous bush; outer radius of thrust plate—in. |
| $m$ | Mass flow per feed hole—lb/sec |
| $M$ | Mass flow from bearing—lb/sec |
| $\gamma$ | Ratio of specific heats of gas—dimensionless. |
| $\alpha$ | Permeability of porous bearings—ft$^2$ |
| $\lambda l$ | Geometric parameter for porous bearings—dimensionless. |
| $\varrho$ | Gas density—lb/ft$^3$ |
| $\mu$ | Gas viscosity—lb/ft, sec |
| $a_s$ | Velocity of sound at supply conditions—ft/sec |
| $N$ | Number of feed holes in each ring of feed holes. |

the adjacent feed hole, and the effect is similar to that of a pocket which increases the area over which the greatest pressure differences act. This increases the bearing strength; the $C_L$ of a bearing with two rings each ¼ of the bearing length from the ends of the bearing is some 25% greater than that for a bearing with only one, central, ring of feed holes. The proximity of the feed holes to the open ends of the bearing results, however, in a greater flow requirement, the ¼ station (two rings each ¼ of the bearing length from the end of the bearing) configuration requiring twice the flow of a half station (single ring) bearing supplied with gas at the same pressure. If the comparison is made between bearings of the same size and carrying the same load, the supply pressure for the ¼ station arrangement is some 25% greater than for the ¼ station bearing and the flow some 20% less. However, the pumping power expended in compressing the gas to the supply pressure will be least for the ¼ station bearing, which is therefore to be preferred in most cases.

The flow pattern within the bearing is improved by increasing the number of feed holes, and this enhances the load coefficient. However, there is little further improvement if the number is greater than 10 or 12. The flow is not influenced by the number of feed holes, other than that reductions in $P_s$ made possible by increases in $C_L$ affect it; the greater the number of feed holes the less the diameter of each hole.

*Length/Diameter Ratio.* The pressure difference across the bearing tends to cause gas to flow circumferentially from the high pressure arc to the low pressure region. The greater the length relative to the diameter, the more serious is this tendency, with consequent reduction in load coefficient. However, the increasing length increases the bearing plan area and this mitigates against the reduced $C_L$ to some degree. The increasing length also reduces the flow requirements. For both simple orifice bearings and porous bearings the optimum length to diameter ratio for least supply pressure to support a given load is about 1.8 : 1; the least pumping power is achieved by a slightly greater ratio of about 2 : 1.

*Flow Regime, Laminar or Turbulent.* The strength of porous bearings is also influenced by the Reynolds Number at the end of the bearing. If the Reynolds Number, which is calculated with twice the radial clearance as the characteristic length, is greater than 500 to 1,000, the load coefficient is less than for purely laminar flow. Turbulence has only a small effect on feed hole types of bearing, the load dropping by some 10% of the laminar flow value for a Reynolds Number in the range 2,000 to 3,000, and then being little different down to the laminar flow value.

## Load Coefficients

If certain simplifying assumptions are made, the variation of $C_L$ with $K_g$ can be computed for a feed hole type of bearing. These computations have no practical design value, but do serve to establish an order of merit when comparing different types of external resistance. They show, in fact, that the bearing with simple orifices is the strongest of the three feed hole types of bearing; annular orifice and capillary bearings are both some 30% weaker.

Experimental evidence on capillary compensated journals is non-existent; that for simple and annular orifice compensation upholds the prediction that the simple orifice confers greater strength. To ensure that the bearing is, in fact, operating in the simple orifice condition some modification to the exit of the feed hole is needed; when this modification has its simplest form the load

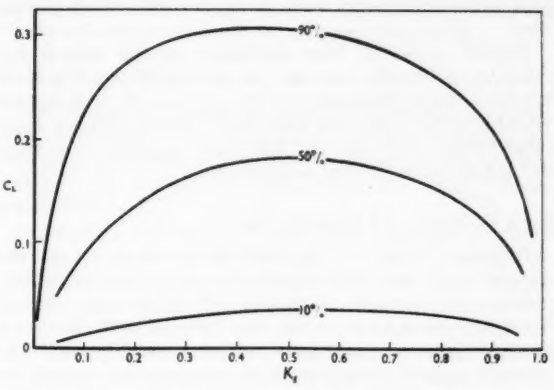



Fig 4.—Load Coefficient as a function of $K_g$. Curves refer to a simple orifice with fully developed pockets; two rings of feed holes at ¼ station; 12 feed holes per ring; length/dia. ratio = 2:1.

coefficient is about 20% greater than that for an annular orifice. If the termination is made more complex, in the form of long circumferential shallow pockets, a further increment of about 20% is gained.[10]

Curves of the load coefficient for simple orifice compensation, plotted against the pressure ratio $K_g$ with eccentricity as a parameter are given in Fig. 4. The curves are for a bearing with two rings of feed holes at ¼ stations, 12 feed holes in each ring and a length/diameter ratio of 2 : 1. They also are for fully developed terminations to the feed holes.

The maximum value of load coefficient (at 90% eccentricity) occurs when $K_g$ is about 0.4, and is about 0.30. Thus a bearing of this configuration would carry more than ¼ lb on each square inch of the plan area for each 1 p.s.i. of pressure difference between supply and ambient; a bearing 2 in. diameter and 4 in. long exhausting to atmosphere and with a supply pressure of 100 p.s.i.g. would carry a load of 240 lb. The curve is relatively flat,

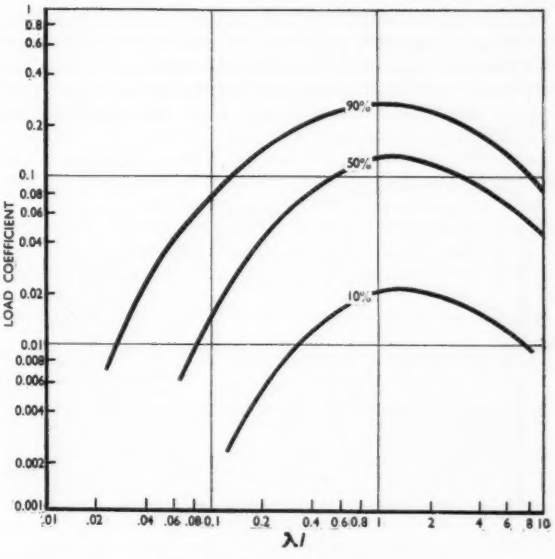



Fig. 5.—Load coefficient against $\lambda l$ for porous bearings. Length/dia. ratio = 2:1; Reynolds No. < 1000.

and small discrepancies in $K_g$ have very little effect on the load.

Similar curves of load coefficient plotted against the ratio $\lambda l$, for porous bearings are plotted in Fig. 5. They are for a length/diameter ratio of 2 : 1 and for a Reynolds Number at the outlet less than 1,000. The maximum value differs little from that for feed hole bearings with fully developed simple orifice compensation.

### Flow Economy and Bearing Choice

Although in certain applications the need to get the highest load carrying capacity from a limited supply pressure might dictate the choice of bearing, more usually the requirement will be for the bearing with the least running cost in terms of gas flow and pumping power. As all three types of feed hole bearing develop their maximum load coefficient at about the same value of $K_g$ the gas flows may be easily compared. If $K_g$ is the same for each case then the gas flows are the same for each bearing if the supply and exhaust pressures are the same. However, the changes in $C_L$ dictate that, to carry the same load as a simple orifice compensated bearing, a bearing with annular orifice or capillary compensation will require a greater supply pressure which leads, automatically, to an increased flow. This increase is of the order of 100%.

The mass flow from a feed hole type bearing may be computed either on the flow through the feed holes or the flow through the gap between shaft and sleeve. The former manner is the more convenient in that it involves fewer variables. For simple orifices the flow through each feed hole

$$m = 6.16 \times 10^{-9} d^2 \rho_s a_s F(\gamma K)$$

where $K = P_d/P_s$

and $$F(\gamma K) = \left[\frac{\gamma}{\gamma - 1}\left(K^{2/\gamma} - K^{(\gamma+1)/\gamma}\right)\right]^{1/2}$$

which is plotted as Fig. 6. This expression for mass flow is applicable to simple orifice type bearings only, but flow from annular orifice compensated bearings can be evaluated in a similar manner.

### Flow Calculations

The flow from a porous bearing can be calculated from an empirical expression quoted by Robinson and Sterry.[2] For bearings with similar pressures, clearances, etc., the flow from a porous bearing is approximately twice that from a feed hole bearing with fully developed simple orifice compensation. Simple orifices discharging into circular pockets have smaller flow requirements than porous bearings, even at the higher pressure needed if they support the same load, but there is little difference between the pumping power requirements of these two types.

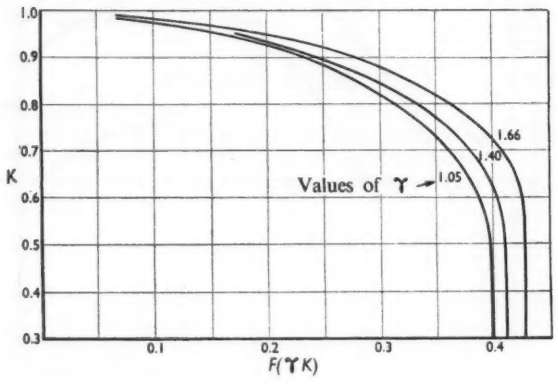



Fig. 6.—*Relationship between K and* $F(\gamma K)$, *where* $K = P_d/P_s$ *and* $F(\gamma K) = [(\gamma/\gamma - 1)(K^{2/\gamma} - K^{(\gamma+1)/\gamma})]^{1/2}$.

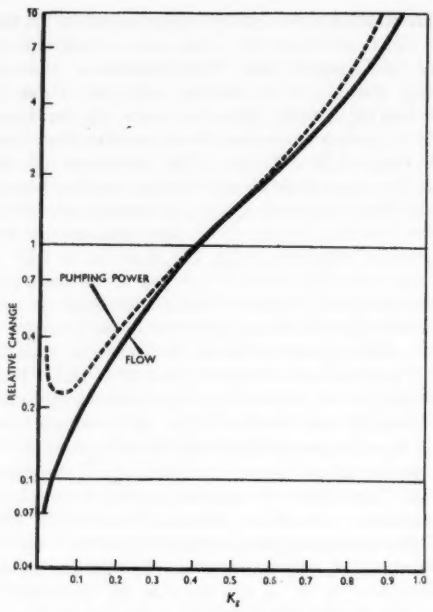



Fig. 7.— Effect of $K_g$ on mass flow and pumping power with constant load, clearance and plan area; $P_a \doteqdot 0.1 P_s$.

Alteration of either the feed hole diameter or the bearing clearance alters the pressure ratio $K_g$ at which the bearing operates. This modifies both the supply pressure needed to support a given load, and the flow through the bearing. If the change in $K_g$ is due solely to the feed hole diameter being reduced, the flow requirements and the pumping power are both reduced, despite the increased supply pressure. The magnitude of the effect is conditioned by the actual values of the pressures, but typical values are shown in Fig. 7. There is a similar reduction in the flow from a porous bearing if $\lambda l$ is made smaller by reducing the permeability, but this in no way lessens the discrepancy between the flow requirement of the type as compared to the simple orifice bearing.

### Design Techniques

In the design of a machine utilizing hydrostatic gas lubrication many of the bearing parameters are fixed by considerations other than the bearing design. The object of the design will usually be to minimize the power expended in compressing the gas. To achieve the lowest supply pressure the bearing loads, both static and dynamic, must be reduced to a minimum, while the bearing plan area must be the greatest possible, subject to the length not being greater than twice the diameter. To a considerable degree these are mutually contradictory, and final choice must be a compromise.

### High Supply Pressure

The clearance has a double effect. A small clearance reduces the gas flow, but limits the maximum tolerable eccentricity. The smaller the eccentricity the less the load

coefficient, and in consequence small clearance implies high supply pressure. Generally, least pumping power will be obtained by using minimum obtainable clearance at the expense of supply pressure rather than by increasing the clearance to obtain higher usable eccentricities. Again compromise decisions are needed in that the expenditure on close tolerance machining needed for small clearances might not be justified in machines with only limited periods of operation.

The parameters most open to modification in feed hole bearings are the feed holes themselves. The optimizations of position and number have been considered earlier, the required diameter is that which gives the selected pressure ratio $K_g$. This diameter can be found by equating the mass flow through the feed holes to that through the bearings. Thus for a simple orifice bearing:—

$$5.65 \times 10^5 F(\gamma K)/K^2 = c^3 D g P_s \left\{1-(K_T/K)^2\right\}/lNd^2\mu a_s$$

where $K_T$ is the ratio of exhaust pressure to supply pressure.

The load, plan area and maximum usable eccentricity together with an assumption of an operating $K_g$ of 0.4 determine the minimum possible value of supply pressure. If a higher pressure can be conveniently used, then an operating $K_g$ less than 0.4 can be selected to conserve power, as discussed above. The feed hole diameter required to give the selected value of $K_g$ can then be calculated.

### Machining and Manufacture

The manufacture of the long circumferential pockets associated with the fully developed simple orifice bearing is discussed in detail by Robinson and Sterry[1]. To get the fine control on pocket depth and on length of arc a jig borer is used, the bearing surface having previously been fine ground.

Feed holes, which typically have a diameter of the order of 0.010 to 0.020 in. for simple orifices, are most conveniently drilled into screwed inserts and then sealed into the bearing bush rather than into the bush itself. If they are recessed below the bearing surface the resulting shallow depression forms the circular pocket enabling simple orifice compensation to be obtained easily, although only at the expense of some loss in load coefficient.

The use of capillaries presents no manufacturing difficulty though the lengths of tube needed to give the required pressure drops would lead to installation trouble. One reported example of a thrust bearing[3], used 10 ft. lengths of tubing, 0.040 in. in diameter.

Porous bearings are made from commercially available sintered bushes and would not normally require any machining operation; this is difficult owing to the tendency of the surface to smear and close the pores. If machining is required, either the pores must be filled during the operation with, for example, common salt or oxalic acid, or else the surface must be etched after machining.

### Bearing Instabilities

Gas bearings are prone to instability phenomena. These may be associated only with certain operating speeds, or may be independent of the relative speeds of the bearing members; for convenience these second are called "Static Instabilities."

In bearings with separate feed holes, the static instabilities are due to the incorporation in the bearing surface of pockets of too great a volume. Richardson[4] recommends that the volume of the pockets should not exceed that contained between the two bearing members. This is essential in journal bearings but pockets of large volume can be tolerated in thrust bearings, provided the difference between the supply pressure and the pocket pressure is very small compared to the difference between supply and exhaust pressures.

### Static Instability

In porous journal bearings the phenomenum of static instability arises only under certain conditions of $\lambda l$ and outlet Reynolds Number. The change from laminar to turbulent flow influences the pressure distributions in this type of bearing to a greater extent than in feed hole bearings; this has been noted already in the effect of the Reynolds Number on the load coefficient. At low values of $\lambda l$, where the load coefficient is little influenced, the bearings are free of instability irrespective of the Reynolds Number; conversely, at Reynolds Numbers less than 1,000 the bearing is statically stable at all values of $\lambda l$. Reduction of permeability is the preferred cure for bearings suffering from this disability, since it reduces both $\lambda l$ and the Reynolds Number.

Instabilities associated with shaft rotation are reported by Montgomery and Sterry[5, 11] and Sixsmith[6]. Both associate the phenomena with vibrations at half the shaft speed and it appears synonymous with the "half speed film whirl" of hydrodynamic gas bearings. Montgomery eliminated the trouble by supporting the bearings in resilient mountings, and in this way speeds of 250,000 r.p.m. were achieved. Sixsmith cured the instability by machining pockets into the bearing surface, communicating with the bearing exterior through a resistance; the pocket volume and the resistance being resonant at the frequency associated with the shaft vibration. The pressure rise in the pocket was out of phase with the shaft displacement and in consequence damped out the vibrations. By these techniques Sixsmith achieved similar speeds. The onset of half-speed film whirl occurs at higher speeds with pressurized bearings than with plain hydrodynamic bearings. Mueller[7] reports speeds in excess of 60,000 r.p.m. with no reference to any shaft instability.

**TABLE 1**
**Journal Bearings for 400 lb at 90% Eccentricity; Length 5 in., Diameter 2½ in., Diametral Clearance 0.004 in.**

| Parameter | Simple Orifice Long Pocket | | Simple Orifice Circ. Pocket | | Annular Orifice | | Porous | |
|---|---|---|---|---|---|---|---|---|
| | $P_s$=min. | $P_s$=225 | $P_s$=min. | $P_s$=225 | $P_s$=min. | $P_s$=225 | $P_s$=min. | $P_s$=225 |
| $K_g$ or ($\lambda l$) .. .. | 0.40 | 0.045 | 0.4 | 0.15 | 0.4 | 0.3 | 1 | 0.22 |
| Load Coeff. .. | 0.304 | 0.153 | 0.25 | 0.153 | 0.182 | 0.153 | 0.3 | 0.147 |
| Supply Pres. .. | 120 | 225 | 142 | 225 | 190 | 225 | 107 | 225 |
| Feed Hole Dia. .. | 0.019 | 0.035 | 0.020 | 0.006 | 0.067 | 0.043 | — | — |
| Mass Flow lb/sec .. | 0.015 | 0.0019 | 0.019 | 0.0027 | 0.035 | 0.023 | 0.023 | 0.006 |
| Pumping Power .. | 1.5 | 0.29 | 2.3 | 0.41 | 4.8 | 3.5 | 2.3 | 0.86 |

The same author reported an increase in bearing strength due to shaft rotation. There are no design data to evaluate this effect quantitatively.

In summary, for applications where long periods of running are envisaged the use of simple orifices feeding into long circumferential pockets is amply justified on the grounds of running economy. For the systems with less usage the simpler type of pockets, or, if a standard type size of permeable bearing is available, a porous bearing might be better. There seems little reason to consider either annular orifice or capillary compensated bearings.

Table 1 illustrates typical figures for bearings to carry a load of 400 lb at 90% eccentricity. The bearing diameter is 2½ in., length 5 in. and clearance (diametrical) is 0.004 in. The gas parameters are those of air at normal temperatures. It illustrates, for porous, simple orifice and annular orifice bearings, the flow and pumping power needed, both at the least supply pressure ($K_g$=0.4 or $\lambda l$=1) and at the reduced $K_g$ which can be tolerated if the supply pressure available is 225 p.s.i.a.

The exhaust pressure is assumed to be atmospheric in all cases, and the pumping power assumes adiabatic compression from $P_a$ to $P_s$. The table amply illustrates the gains in economy which are made possible both by the long pocketed simple orifice bearings and by operating at a $K_g$ less than that at which the load coefficient is greatest.

## THRUST BEARINGS

Thrust bearings operating on the hydrostatic principle usually take the form of flat plates, although on occasion both conical and spherical surfaces have been used; step and collar bearings have been developed. The step bearing is usually fed through a shallow central pocket with a simple orifice forming the external resistance. The pocket volume should be small to avoid instability, although this is not as critical as with journal bearings, because the pressure drop across the external resistance need not be high[8].

Licht and Fuller[9] recommend that loads and flows in gas thrust bearings should be calculated as for an incompressible fluid; the compressible flow formulæ are complex and tend to over-estimate the load that is carried.

The load calculation is based on the pocket pressure, the ambient pressure and the bearing dimensions:—

$$\text{Load} = \tfrac{1}{2}(P_d - P_a)(r_o^2 - r_i^2)\log_e(r_i/r_o)$$

The same factors, together with the design clearance, determine the mass flow:

$$M = \frac{1.33\times10^{-2}\pi c^3 g(P_d^2 - P_a^2)}{P_d \log_e(r_o/r_i)}$$

while the flow, $P_d$ and $P_s$ enable the diameter of the simple orifice restrictor to be calculated, as for the journal bearing. Similar expressions can be used for the load and flow through a collar bearing, in which the gas is admitted through a ring of feed holes, treating the pitch circle diameter of the feed holes as equivalent to the pocket diameter.

Although the high standards of flatness obligatory in hydrodynamic thrust bearings are not essential in the hydrostatic variety, it is obvious that economy in gas consumption can only be obtained if clearances are kept small.

### Temperature Effects

The effects of operating hydrostatic gas bearings over a wide temperature range have only been investigated for thrust bearings with capillary compensation[3]. Under conditions of constant load and pressure an increasing temperature leads to an increase in the operating clearance. By examination the same would be expected for a thrust plate with orifice compensation.

In a journal bearing the clearances cannot vary with temperature, and changing the operating temperature modifies the operating conditions. Increasing temperature increases both the gas viscosity and the velocity of sound in the gas. These both modify $K_g$ which will tend to increase. Assuming that $K_g$ in the coldest condition is less than 0.4, then increasing temperature will marginally increase the bearing strength. With a porous bearing there is no change in $\lambda l$ but the increase in viscosity will reduce the mass flow.

## APPLICATIONS

The relative freedom of the bearings from viscosity effects enables operation at low temperature to be considered, although optimum operating conditions can only be obtained at the expense of large flows. Such an operating condition was considered for a heavy water production plant, a hydrogen expansion turbine operating at about 50°K being supported on hydrostatic gas bearings.

Hydrodynamic gas bearings will be used where gas lubrication is required, but where the unit loadings are too great to permit the use of hydrodynamic bearings. One example is in the larger circulators associated with reactor cooling circuits; the supporting gas flow might well be that required to make up circuit losses. Bearing operation in a region of high flux density has required pressurized gas bearings, the relatively low speed and high loads making self-acting bearings impracticable. Other experimental apparatus, used in the measurement of cross-sections and neutron spectra, have used pressurized bearings, since by this means higher rotational speeds (and greater resolution) have been obtained.

### Freedom of Movement

The ability to separate the bearing members at zero rubbing speed has been exploited in remote handling gear using spherically seated bearings to confer freedom of movement in three planes. The movement of heavy shielding in irradiation facilities could also utilize a gas bearing principle; this has already been adopted in other industries to assist the movement of heavy jigs and tools.

The freedom from rubbing at low speeds widens the choice of materials that can form bearing pairs. Anti-galling properties are not essential, but, unless the bearing duties are very light, it is advisable to minimize the overload conditions which might arise due to mal-operation.

(*Translations, page* 122.)

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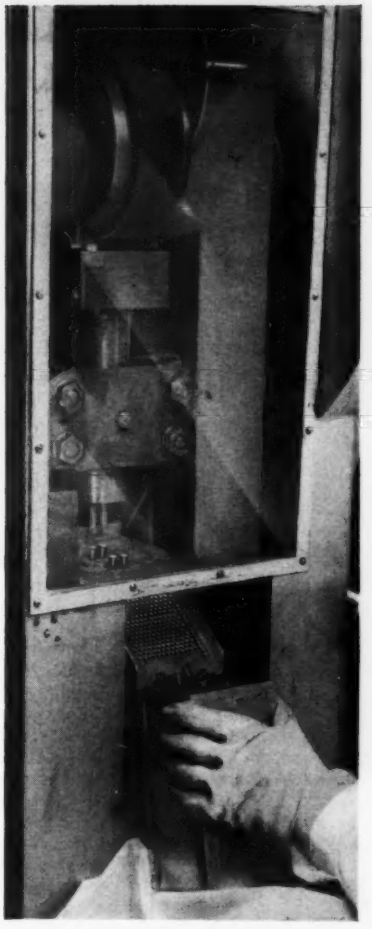
# Ceramic Fuel Production In France

**The manufacture of ceramics is one of the oldest arts. For fuel element applications, to the traditional requirements of strength and heat resistance are added dimensional accuracy, high density, high thermal conductivity and radiation stability.**

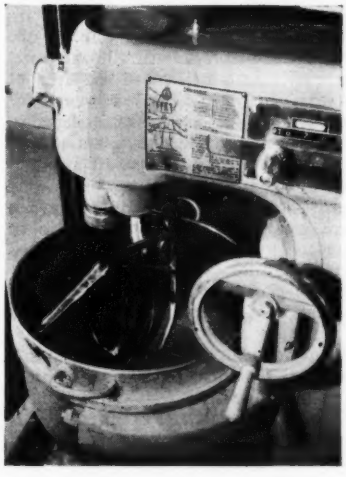


Compacting the uranium oxide powder into pellets.

ALTHOUGH the present power programme in France is based on the use of natural metallic uranium, an intensive programme of research is under way on ceramic fuels. To supply the needs of the development programme and also any reactor incorporating ceramic fuels (as, for example, a light water-moderated high flux test reactor) CEA placed a contract in October 1957 with the Compagnie Industrielle des Ceramique Electronique, an associate of the Compagnie Generale de Telegraphie sans Fil, for the immediate construction of a uranium oxide pellet production plant. The Company has considerable experience in the precision ceramic field and has also undertaken a number of development projects for the CEA. Amongst these is the building of a 1-2 BeV linear accelerator at Orsay near Saclay, based on C.S.F.'s 28 kW klystrons.

By April, 1958, six months after the first breaking of ground, a 30,000 sq. ft factory had been erected in the grounds of C.S.F.'s Research Centre at Corbeville, situated a few kilometres from Saclay. Production of the first pellets began immediately. The complete plant has a production capacity of 25 tons per annum, which is equivalent to a yearly output of about 1 million pellets 1 cm dia. by 2 cm high; it is designed to accommodate a uranium enrichment of up to 5%.

A wide range of experimental compacts has been made including tubes, but the main production effort is directed towards small pellets as close dimensional tolerances are more easy to achieve and large diameters result in excessive central fuel temperatures.

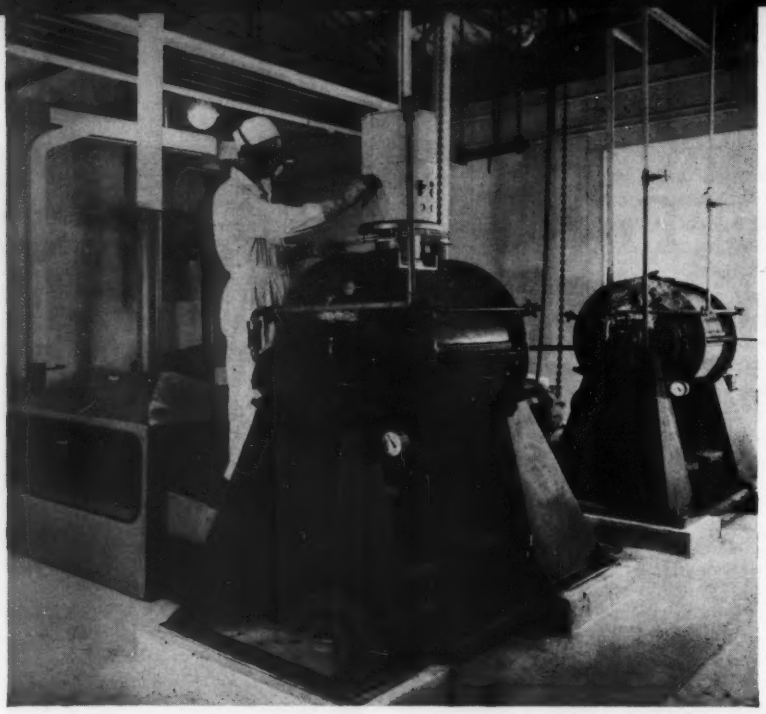


Mixing in the binder and lubricant.

### The Production Plant

When *Nuclear Engineering* inspected the plant, uranium oxide of 1.5% enrichment was being handled. The powder is delivered from Le Bouchet, sealed in polythene bags in steel drums, each drum containing 50 kg. On arrival at Corbeville, the drums are transferred to store and segregated into stacks, four high. The drums are opened in turn in a glove box and lots of 10 kg weighed out. The oxide is then fed to a ball mill where, with uranium balls, it is ground down to a mean particle size of about 1$\mu$, the overall range being from approximately 0.1 to 5$\mu$. From the mill it is transferred to one of three mixing chambers where, to 20 kg batches, camphor is added as binder and stearic acid as lubricant. The resultant mixture has the agglomerates broken down in a machine in which rotating brushes pound it through a grid of $\frac{1}{2}$ mm dia. holes, on to a conveyor which carries it through a drying chamber, where under reduced pressure, it is maintained at 40° C, for 25 minutes.

From the dryer, the powder is transferred to drums, which are transported into the adjoining shop, where the presses and ovens are located. In each compaction machine equal volumes of powder are transferred from a local hopper continuously maintained at constant level, to a pair of tungsten carbide dies. Under a pressure of about 20 tons/in.$^2$ two pellets are formed at a time; these are automatically ejected into a collection bin at a rate of, approximately 50 per minute and at this stage, 1% are removed for weighing and dimensional checks. The pellets are sintered in eight molybdenum-wire electric resistant furnaces, under an atmosphere of hydrogen. Each furnace is capable of taking a loading of 150 lb and is arranged on a five-day cycle. After flushing with hydrogen, the temperature is brought up to 1,600°C over a period of two days, held there for six hours and allowed to cool over the following three



Uranium ball mills which grind the powder to a mean diameter of one micron.

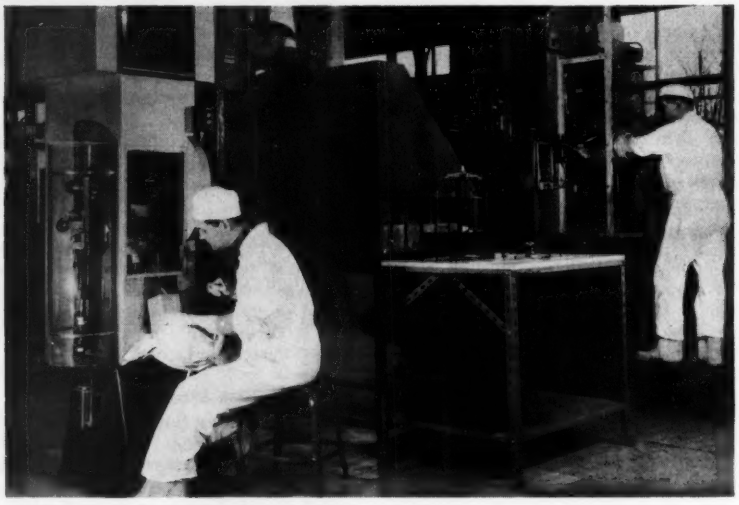
days; the hydrogen atmosphere is maintained throughout.

During the sintering process, a 15% shrinkage takes place, but dimensional tolerances of 0.1 mm. are achieved on production runs. Grinding and polishing machines have been provided in the shop, but these are no longer being used.

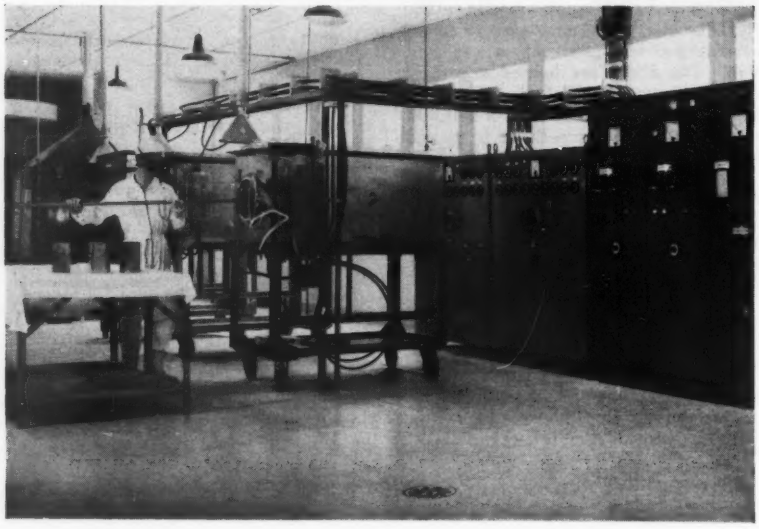
Finally the pellets are packed in 20 cm-long aluminium tubes for shipment to the CEA. Strict quality control is maintained throughout manufacture. A representative sample of the finished product passes through not only dimensional tests, but also density (which is maintained at $10.3 \pm 0.1$ g/cc) and purity analyses.

**Safety Precautions**

Through most of the plant, the operators are obliged to wear face masks because of the dust hazard and individual machines are enclosed and provided with their own air-conditioning system. The ventilation for the whole plant is fed from a centralized system with a throughput of filtered air of 10,000 $ft^3$/min.



Automatic compaction machine with test equipment in the background.



General view of the sintering room with one furnace being charged.

Full changing facilities are provided for the operators, and a shower on completing the day's work is obligatory.

The production plant, the only one of its kind in Europe, will not only meet the requirements of France and even of Euratom for the next few years for research and for reactor fuel elements, but will also provide pilot plant experience for the construction of a larger plant which is at present in the drawing board phase. This is likely to have a much greater capacity and will also be designed to cater for fully enriched uranium oxide.

Out-of-pile tests on the pellets have given encouraging results, and a number of the outer fuel channels in G2 are to be loaded with uranium oxide elements to provide radiation damage information. From the out-of-pile tests taken in conjunction with American experience, it is expected that a total irradiation of 10,000 MWd/t can be achieved.

# INTERNATIONAL SYMPOSIUM on Nuclear Fuel Elements

By A. STRASSER
*(Nuclear Development Corporation of America)*

A review on the first International Symposium on Nuclear Fuel Elements held at Columbia University, U.S.A.

ON January 28 and 29, Columbia University in New York City was host to the First International Symposium on Nuclear Fuel Elements. The Symposium was sponsored jointly by Columbia University and Sylvania-Corning Nuclear Corporation with Dr. H. Hausner as secretary of the organizing committee. The proceedings will be published in book form, edited by H. Hausner and J. Schumar. In addition to 13 speakers from the U.S.A., there were two from France, and one each from the U.K., Germany and Canada. Of a total of about 450 delegates there were more than 70 from outside the U.S.A.

**Solid Fuel Elements—Present, Future,** by S. B. Roboff (Sylvania-Corning Nuclear Corporation).

Mr. Roboff made a number of predictions for the future which can be summarized as follows:—

1. Solid fuels will be used in the majority of reactors, liquid fuels will be employed in special cases only.
2. Ceramic fuels will continue to gain importance with the increasing demand for higher temperatures and longer burn-ups.
3. Metal and cermet fuels will gain new favour as new high temperature alloys are produced.
4. Reactors using unclad fuel will be developed; these reactors will have a coolant purification system.
5. Standardization of fuel elements will be adopted with attendant cost reduction.
6. Fuel elements will become the key components of power reactors developed for the direct conversion of nuclear heat through the use of thermo-electric devices.

**Uranium and Uranium Alloy Elements,** by F. Foote (Argonne National Laboratory).

Based largely on data previously published, this paper gave an excellent review of the subject—uranium and uranium alloy elements.

**Uranium-Zirconium Hydride Fuel Elements,** by U. Merten (General Atomic Division, General Dynamics Corporation).

A prompt negative temperature coefficient is one of the chief attributes of these fuel-moderator elements which were described and exhibited at the Geneva Conference in September. A water-cooled reactor core comprised of such fuel elements is undergoing extensive transient testing and, to date, it has been demonstrated that a step function of two dollars worth of excess reactivity can be inserted without boiling the coolant.

**Thorium-type Fuel Elements,** by C. Woolsey (Atomics International).

The inherent attractions of the $U^{233}$ fuel cycle have spurred thorium fuel element development. The technological advantages of thorium alloys are a higher allowable temperature and burn-up than purely uranium-base alloys. Thorium oxide-base ceramics are very stable materials, as might be expected of ceramic fuels.

Reactors for which thorium is being considered are the Sodium Reactor Experiment (SRE), the Sodium Graphite Reactor (SGR), the Advanced Epithermal Thorium Reactor (AETR), the Consolidated Edison Thorium Reactor (CETR), and the Elk River Nuclear Reactor; Borax IV is presently using thoria-base elements. Some of the fuel element descriptions given, appear in Table 1, and in Table 2 are quoted the highest temperature and burn-up irradiations for a Th-10U alloy so far reported. Cost of thorium is $20/lb, which is similar to natural uranium and is to be compared with $15/g for $U^{233}$ and $12/g for plutonium.

Argonne National Laboratory's $ThO_2$-$UO_2$ irradiations have gone to several atom percent burn-ups in 45°C water without detrimental effect. At higher coolant temperatures, Pb bonding is desirable to minimize central fuel temperatures.

On the fabrication side, the results of producing thorium alloys by casting are encouraging both technologically and economically. Dr. Woolsey predicted that the use of thorium in nuclear reactors will increase rather slowly in the coming years, but after confidence has been gained, it will increase in a manner similar to that of nuclear reactors in general.

**Plutonium Fuel Elements,** by R. E. Tate (Los Alamos Scientific Laboratory).

Dr. Tate's meticulously complete coverage of the subject was a valuable addition to the literature and it is unlikely that a better summary of plutonium fuel element technology is available. In it

**TABLE 1—Planned Fuel Element Characteristics**

| | SRE | CETR | Elk River | Borax IV |
|---|---|---|---|---|
| Fuel | Th-7.6 U alloy | $ThO_2$-5.7 $UO_2$ | $ThO_2$-4/10 $UO_2$ | $ThO_2$-6.4 $UO_2$ |
| Cladding | Stainless steel | Stainless steel | Stainless steel | Al-1Ni (M-388) |
| Bond | NaK | He | He | Pb |
| Fuel dia. (in.) | 0.750 | 0.263 | 0.407 | 0.225 |
| No. of rods/element | 7 | 206 | 25 | 47 |
| Coolant | Na | $H_2O$ (press.) | $H_2O$ (boiling) | $H_2O$ (boiling) |

**TABLE 2—Highest Temperature and Burn-up figures for a Th-10U Alloy**

| Burn-up (a/o) | Central (°F) | Surface (°F) | Dia. Increase (%) | Vol. Increase (%) |
|---|---|---|---|---|
| 0.66 | 1,252 | 1,022 | 2.3 | 5.1 |
| 1.14 | 1,100 | 900 | 1.7 | 4.1 |

**TABLE 3—Plutonium Fuelled Reactors**

| Reactor | Date Pu Used |
|---|---|
| Los Alamos Fast Reactor (U.S.A) | 1946 |
| NRX (Canada) | 1951 |
| ZEPHYR (U.K.) | 1954 |
| BR-1 (U.S.S.R.) | 1955 |
| MTR (U.S.A.) | 1956 |
| BR-2 (U.S.S.R.) | 1956 |
| BR-5 (U.S.S.R.) | recently |
| PRTR (U.S.A.) | 1960 (scheduled) |
| EBR-II (U.S.A.) | 1960 (scheduled) |
| LAMPRE-I (U.S.A.) | planned |
| BN-50 (U.S.S.R.) | planned |

fuel elements of past, present and planned plutonium fuelled reactors were described. A summary of metallic plutonium alloys systems, plutonium-base ceramic systems and plutonium compounds was also given.

**Uranium Dioxide Elements,** by O. J. C. Runnalls (Atomic Energy of Canada, Ltd.).

In the fabrication of $UO_2$ elements, thermal conductivity can be improved by an annealing treatment after sintering. Steam sintering at 1,400°C, annealing 1 hour in hydrogen and cooling in hydrogen, produced compacts which had 25% higher thermal conductivity than compacts where the annealing treatment was omitted. Sinterability has been improved by wet ball milling, and additives such as $TiO_2$ and $Nb_2O_5$. Fused and crushed $UO_2$ gives the best final densities (above 90% of theoretical).

Hot swaging of clad $UO_2$ rods at 600°C is being tried for the NPD rods, but high tube diameter to tube wall thickness ratios are difficult to accommodate; the Shippingport reactor has a ratio of 30, NPD a ratio of 40. Cracks have been found to propagate from the inside of the cladding during swaging of NPD rods and this has caused the rejection of swaging as a fabrication process for at least the first NPD core.

Clearances between $UO_2$ and Zircaloy cladding have been found to be less critical than thought heretofore. Variation of diametral cold clearance (on a 0.7-in. diameter rod) from 0.005-0.017 in. did not appear to make an appreciable difference in operating characteristics.

Dr. Runnalls commented on the effect of O/U ratio on properties. A ratio of 2.15 reduces thermal conductivity sufficiently to increase central temperatures and consequently fission gas release rates by a large magnitude, compared to material with a ratio of 2.0. The O/U ratio appears to have little, if any, effect on the expansion coefficient.

Fission gas release rates may also vary considerably between materials fabricated by different methods. It has been suggested that ultimate fission gas release may be limited by the partial pressure of fission gas already released.

Dr. Runnalls suggested that $UO_2$ fuel elements be rated and specified by their maximum power generating capabilities rather than by their maximum central temperatures.

**Plate-type Elements,** by J. Cunningham (Oak Ridge National Laboratory).

Dispersion-type elements, particularly those based on aluminium and stainless steel, were reviewed. The stability of these elements to high fuel burn-ups is the reason for their widespread use in enriched fuel reactors.

**Tubular Elements,** by W. Maxwell (General Nuclear Engineering Corp.).

Tubular fuel elements have a number of advantages, including better mechanical properties and heat transfer characteristics. Examples of tubular elements being manufactured were given as:—

(1) The CP-5 coextruded Al clad, U-Al alloy tube.

(2) The Martin diffusion bonded Al or stainless steel-$UO_2$ dispersion tube.

(3) The Zircaloy-2 clad U alloy coextruded tube made by Nuclear Metals Inc.

Fabrication of tubular elements has its problems, but the potential advantages of these elements will make tubular elements increasingly popular.

**High Temperature Fuel Elements,** by A. Strasser (Nuclear Development Corporation of America).

A summary of the applications, requirements and materials for high-temperature fuel elements was given, as well as a review of various laboratories' test results on these elements. New data were presented on preliminary tests made by NDA on fuel elements to produce ~1,370°C with He coolant in a process heat reactor. Fuel and fission product diffusion data were presented on fuel, clad with self-bonded SiC, $Al_2O_3$, $Al_2O_3$-Cr, Nb, and NiAl. Diffusion and reaction tests were made for short times at 1,370°C. Fission product diffusion was measured by low temperature, low flux irradiation with out-of-pile reheating at 1,370°C for short times. Of the materials tested $Al_2O_3$ showed some desirable properties as a fuel element component. It was concluded that fuels such as uranium oxides and carbides have an established future. For clad and matrix materials, metals, intermetallic compounds, and graphite have particular potential based on their intrinsic properties rather than tests as fuel element components.

**Fuel Elements for Gas-cooled High Temperature Reactors,** by Dr. G. Matz (Degussa, Germany) substituting for Dr. Boettcher.

Dr. Matz discussed the evolution of higher and higher temperature gas-cooled reactors, particularly in the U.K. and the necessity for ceramic (oxide) cladding. Of special interest was the citation of Degussa's non-nuclear experience with alumina tubes. A radial heat flow of 30 W/cm³ in a temperature range of 1,100°-1,200°C did not impair the "tightness" of the tubes, in spite of grain growth caused by long exposures at these temperatures. Mention was made of the UC-fuelled graphite balls developed by Degussa for the BBC-Krupp gas-cooled reactor. A UC-graphite cylinder is placed in the base of a ball and the cylinder is sealed off with a plug "cemented" in the graphite. The sealing method was not described, but was said to be technologically and economically "sufficient." Central fuel temperatures of 1,500°C or higher are expected. A dispersion of fuel in the graphite ball was also considered but apparently not made. A final decision on the details of the "potato" fuel element has not been made either.

A test reactor is being planned to irradiate prospective fuel elements.

**High Temperature Creep of Uranium-loaded Graphites,** by L. Green, Jr. (Aerojet-General Corporation).

Graphite bodies studied as having possible application to nuclear rockets, had up to 0.350 g/cm³ uranium. A grade containing 0.125 g/cm³U with an effective graphite density of 1.73 g/cm³ had the best mechanical properties. Tensile strength and creep were measured up to 2,400°C and 100 minutes. In the temperature range 1,500-1,900°K, stresses of 500-2,000 p.s.i. appeared to be useful working stresses to produce 0.1% creep in short times (minutes to a few hours). It was estimated that the effect of radiation on creep may cause a significant increase in rate. The added effect of fission fragments is also an unknown and the magnitude of the effect was not estimated.

**Ceramic Fuels in France—Research and Development,** by A. Accary (Commisariat à L'Energie Atomique, Saclay) and B. de Lasteyrie (Cie pour l'Etude et la Realisation de Combustibles Atomique, Bonneuil).

Dr. Accary described a pilot plant for the production of two tons of $UO_2$ pellets per month, and associated research on the effect of $UO_2$ specific surface on low temperature sintering of pellets. A low temperature laboratory fabrication process for high-density UC and U-UC cermets by "pressure sintering" briefly described at Geneva, was discussed, in addition to the reactivity of UC with zirconium. Measurements of the coefficient of expansion of UC showed that there was no ratchetting as in uranium metal. Dr. de Lasteyrie also went into the metallic fuel development and production. As well as unalloyed uranium, low molybdenum and high (10 w/o) molybdenum content alloys are being used.

**Fuel Element Fabrication and Fuel Element Problems in the U.K.,** by G. Greenough (U.K.A.E.A.).

Dr. Greenough was substituting, on very short notice, for Dr. Hardy of Risley, who was at home in bed, recovering from

the smallpox inoculation required for entry into the U.S.A. A general organizational picture of the various laboratories was described first. Fuel element research is supported by the consortia at a rate of £400,000/year and by the Government at £1,000,000/year. Annual fuel element production in 5 years is expected to be about 1,100 tonnes which might comprise $10^5$ fuel elements.

In the Calder Hall-type elements the maximum useful temperature is below the $\alpha$-$\beta$ transformation point (660°C). Of the 50,000 Calder Hall elements which have been taken out of the reactor, there have been only 22 failures. Of the 22, six failed because they were faulty prior to insertion in the reactor, or were damaged on insertion into the reactor. The remaining 16 failed in service at the coldest spot (200°C). Grain growth and strain induced grain boundary porosity in the Magnox cladding, was shown to be the cause of the leaks at these points. These defects have been corrected by producing Magnox of refined grain size and removing the source of stress in the element design.

An interesting reactor development schedule was presented. The time interval between the date of decision to design and the date of criticality of a reactor was shown as five years.

**Corrosion Problems**, by J. E. Draley (Argonne National Laboratory).

Reviewing the very extensive corrosion field, Dr. Draley concentrated on the subject of water corrosion of uranium alloys and structural materials. Very long time water corrosion test results on type 1100 aluminium alloys were presented.

**Fuel Elements Behaviour under Irradiation,** by L. W. Kates (Sylvania-Corning Nuclear Corporation).

The effects of radiation on the physical and mechanical properties of fuels and cladding materials were discussed, including a survey of the dimensional stability of fuels. An interesting new result, obtained by Battelle Memorial Institute concerned a 0.1-in. diameter UC rod, made by arc welding which was examined after 2,000 MWd/t burn-up having operated with a central temperature of 770°C. Total fission gases released amounted to 0.1% and only micro cracking of the specimen was evident.

**Various Types of, and Fabrication Techniques for, Fuel Elements,** by J. F. Schumar (Argonne National Laboratory).

Mr. Schumar compared the complex techniques required for today's high-performance elements to the "old days" when a few men with strong backs assembled a core loading of CP-3 fuel elements in a matter of hours. One new technique which he hoped would start a trend toward simplification again is diffusion bonding of fuel elements. The Army Low Power Reactor (ALPR) aluminium-clad, U-Al alloy fuel elements are being produced in this manner. Elemental silicon powder is placed on the surfaces to be joined and the surfaces are then heated under slight pressure. The silicon metal produces an oxide free aluminium surface, and further forms an aluminium-silicon eutectic. The eutectic in turn forms the bond between the aluminium surfaces. A similar process is used to close off the tube ends on the aluminium-type Borax IV fuel elements.

The EBWR and EBR-II fuel element fabrication procedures were described, including the remote injection casting of the fission alloy fuel pins.

**TABLE 4—Power Reactor Costs**

| | GCR | SGR | OMR | PWR |
|---|---|---|---|---|
| % Fuel cost .. | 21 | 38 | 52 | 37 |
| % Capital cost | 70 | 51 | 36 | 52 |
| % Operation cost | 9 | 11 | 12 | 15 |

**Engineering of Fuel Elements for Low Cost Fabrication and Reprocessing,** by R. B. Gordon (Atomics International).

One of the most nebulous, yet one of the most important phases of fuel element technology concerns cost. Dr. Gordon said that to date, fuel costs represent 20% to 50% of the total fuel cycle cost. Data were given for four reactor types in Table 4. The net fuel costs for the reactors quoted range from 2.5 to 5 mill/kWh based on relatively high burn-up assumptions. A relationship was given that fuel costs vary about inversely with the square root of the burn-up. The fabrication cost is about 30% and reprocessing about 10% of the total fuel cycle cost when fabrication costs of $UO_2$ and U-Mo alloy fuel elements are compared; the first types range from $80 to $180/kg and the second from $30 to $70/kg. The presently achievable higher burn-up of $UO_2$, however, makes the $UO_2$ fuel cycle costs more attractive. For 2.5% enriched uranium metal slugs the prices were quoted as $19.58 for cast and $28.27 for wrought material.

**TABLE 5—Zircaloy Break-even Costs**

| Reactor | $\%U^{235}$ | $/lb Zircaloy-2 |
|---|---|---|
| NPD .. .. | 0.7 | 104 |
| SGR .. .. | 1.8 | 57 |
| Yankee .. | 2.6 | 51 |
| MSR .. .. | 3.6 | 44 |
| VBWR .. | 93.0 | 10 |

"Break-even" prices for Zircaloy-2 cladding were given (Table 5). These are the prices at which the lower cost of the uranium inventory and burn-up is just balanced by the difference in cost between Zircaloy and stainless steel at $5/lb. Zirconium has an obvious advantage in low enrichment reactors. The savings possible by the use of aluminium cladding instead of Zircaloy (making proper reactor performance adjustments) were calculated to be in the region of $27/kg U.

**TABLE 6—Fuel Cycle Costs in mill/kWh.**

| Enrichment | Aqueous | Pyromet |
|---|---|---|
| 2.5% | 6.23 | 4.19 |
| 3.5% | 4.21 | 3.49 |

An interesting cost comparison was made for rod bundle type fuel elements containing 19, 37 and 61 rods. The figures were 4.97, 4.92 and 5.12 mill/kWh respectively. This is the result of the interaction of a number of variables such as number of rods, number of bundles required, and frequency of refuelling.

Fuel cycle cost estimates were given for aqueous-direct and pyrometallurgical remote reprocessing methods for uranium metal after 3,000 MWd/t burn-up; these are shown in Table 6.

**Fuels for Reactors of the Future,** by W. K. Davis (Vice-President of the Bechtel Corporation and former Director of the U.S. AEC Reactor Division).

At the dinner in the evening following the first days' session, Mr. Davis discussed a number of subjects vital to the type and economy of reactors to be built in the future. He suggested that the economic reactors of the future would probably be the boiling water, organic, and high-temperature gas-cooled reactors. The 50% cost reduction necessary to make competitive nuclear power will come from reduction in capital and fuel cycle costs. Reduction of either cost will be difficult but necessary. The key to fuel element fabrication cost reduction lies in large-volume production and reprocessing of similar types of fuel elements. Ten or twenty large-size reactors would be required for the utilization of sufficient quantities of elements.

Cost reductions can be realized by changing some of our core design philosophies. Mr. Davis criticized the combination of safety factors whose nature is statistical, such as hot channel factors and peak-to-average power ratios. Such practice leads to excessively conservative designs at the loss of economy. Data collection from operating cores was emphasized as vital to future, more economically designed cores. There is a reluctance to instrument operating reactors sufficiently for this purpose.

On the subject of natural uranium metal, Mr. Davis felt that 4,000-6,000 MWd/t burn-up is required to compete with slightly enriched $UO_2$ in the U.S.A. Pessimism was expressed on future large-scale utilization of heavy water-moderated reactors, unless the heavy water price could be reduced to half of its U.S. price ($28/lb). The need for breeder reactors would arise in about the year 2000 and the development of breeders should not interfere with the development of economically useful, non-breeding power reactors today.

# Neutron Irradiation Effects

## Report on the notched-bar and hardness tests, made on a Ducol W.30 steel plate

THE effects of neutron irradiation on the ductile-brittle transition temperatures of weldable structural steel plates are fully discussed in a paper* dealing with the examination of a welded Ducol W.30 steel plate of 4¼ in. thickness, prepared by R. C. Burnett, J. M. N. Allen and D. R. Harries of the AEA Research Group at Harwell. Their report describes the notched-bar and hardness results on Ducol W.30 steel plate after irradiation at 50°-60°C and 130°-140°C.

The 4¼-in.-welded plate, with the weld laid down transverse to the direction of rolling, was first preheated at 200°C. The weld consisted of multiple passes with ¼ in. diameter high-tensile electrodes made with automatic welding machines. The plate was normalized from 950°C and the machined specimens stress relieved at 675°C.

### Testing Specimens

In testing, single-notch Izod-type specimens 2⅜ in. long and 10 mm square with a V-notch 2 mm deep, 0.25 mm root radius and 45° included angle, were machined from various layers in the parent plate and weld metal. The specimens were cut with their lengths in the principal direction of rolling and notched in a face perpendicular to the surface of the plate after irradiation. The specimens were then placed in a slow bending jig and ethylene glycol was used for tests above room temperature and alcohol-$CO_2$ mixtures for the lower temperatures.

### Method of Irradiation

Enclosed in 1 in. diameter isotope cans, evacuated and filled with helium, the specimens were irradiated in horizontal channels set near the fuel elements in Windscale Pile 2. Positions of equal flux intensity at each end of the channels were utilized for the irradiations so that specimens could be subjected to the same neutron flux at two different temperatures. The temperatures in the respective flux positions were 50°-60°C and 130°-140°C and the calculated thermal flux about $4.35\times10^{12}$ n/cm², sec. The specimens were left in the pile for 130 and 243 days, giving estimated integrated neutron flux levels of $4\times10^{19}$ and $7.6\times10^{19}$ n/cm². In order to distinguish long time heating effects on the ductile-brittle transition temperatures from those arising from neutron irradiation, mixtures of specimens from all levels in the parent plate were soaked at 60°C and 140°C for 126 days.

The notched-bar test results are summarized in the table below and the ductile-brittle transition temperatures quoted are those for which the curves pass through the 50% fibrous level.

| | Level | Transition Temperature °C 50% Fibrous Fracture | | | | |
|---|---|---|---|---|---|---|
| | | Unirradiated | Irradiated | | | |
| | | | 50° – 60°C | | 130° – 140°C | |
| | | | $4\times10^{19}$ n/cm² | $7.6\times10^{19}$ n/cm² | $4\times10^{19}$ n/cm² | $7.6\times10^{19}$ n/cm² |
| Parent Plate | 1 and 2 | 0 | 35 | 71 | 76 | 73 |
| | 3 and 4 | 7 | 40 | 72 | 65 | |
| | 5 and 6 | 3 | 40 | 85 | 65 | 81 |
| Weld Metal | 1 | −30 | 58* | 100* | 75* | 105* |
| | 3 | − 7 | | | | |
| | 5 | −18 | | | | |

* *Mixture of specimens from all levels.*

Soaking at 60°C and 140°C for 126 days produced no significant changes in the transition temperature of the unirradiated specimens but the ductile-brittle transition temperatures were significantly increased by the irradiation, the magnitude of the increases being greater after irradiation to $4\times10^{19}$ n/cm² at 130°-140°C than at 50°-60°C. Only minor changes occurred in the transition temperatures of the parent plate specimens when the dose was increased from $4\times10^{19}$ to $7.6\times10^{19}$ n/cm² at 130°-140°C and it appears that the damage had saturated. The weld metal, however, exhibited a further rise in transition temperatures when the dose was increased, the damage approaching saturation at a higher temperature than for the parent plate. Extending the irradiation dose from $4\times10^{19}$ to $7.6\times10^{19}$ n/cm² on both the parent plate and weld metal specimens irradiated at 50°-60°C approximately, doubled the increases in transition temperatures. Although there was a large scatter in the energy to fracture values, the results showed that the energies of the parent plate specimens were lowered after irradiation to $4\times10^{19}$ n/cm². The decreases were most pronounced at temperatures corresponding to the ductile portions of the fracture transition curves and after irradiation at 130°-140°C. Increasing the dose to $7.6\times10^{19}$ n/cm² at both irradiation temperatures did not result in further significant changes.

The energies of the weld metal were affected to a greater extent by the irradiation than those for the parent plate. The results showed that there is a large scatter but there is a significant increase in the hardness after irradiation. It was not possible, however, to deduce whether the hardness for a given neutron dose is dependent on the irradiation temperatures within the range studied.

### Results of Irradiation

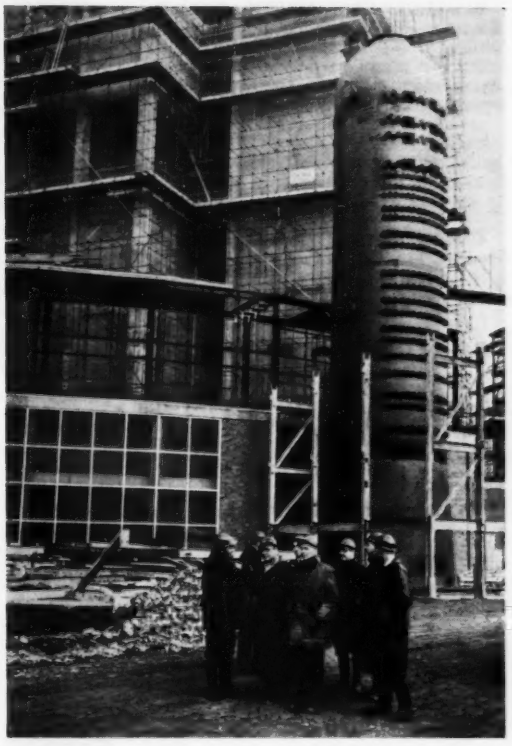
In summing up it is found that when assessed on the fibrous areas of the fractures of specimens tested in slow bend, the ductile-brittle transition temperatures of the parent-plate materials are raised from about 30°C to 38°C and 70°C after irradiation to $4\times10^{19}$ n/cm² at 50°-60°C and 130°-140°C respectively. Increasing the dose to $7.6\times10^{19}$ n/cm² at 50°-60°C results in further elevation of the transition temperature to 75°C but makes little difference to samples irradiated at 130°-140°C.

With the exception of the higher temperature lower dose case, transition temperatures rise to values about 50% higher than those of the parent metal.

Irradiation induced increases in transition temperatures are accompanied by decreases in the energies to fracture in the slow bend test and an increase in the hardness.

* "The effects of neutron irradiation on the ductile-brittle transition temperatures of weldable structural steel plates." A.E.R.E. M/R 2536.

# *World News*



During their visit to Britain for the signing of the U.K.-Euratom agreement, the five-member Commission from Euratom visited the Berkeley power station where progress has passed the half-way stage. This view shows one of the boilers recently erected, outside No. 2 reactor.

## International

**THE FIRST MEETING** of an IAEA panel of authorities on civil liability and state responsibility for nuclear hazards, was held in Vienna on February 23. The legal responsibility for nuclear damage not compensated by private liability, and the unification of rules regarding civil liability and emergency measures after nuclear incidents, were discussed.

**A DECISION** by IAEA's Board of Governors has been reached on the conditions under which Japan will be permitted to buy three tons of natural uranium from the Agency. There are safeguards intended to prevent the loss or diversion of source and special fissionable material from peaceful purposes and rules to avoid hazards to life and property.

**THE THIRD INTERNATIONAL** project undertaken by the Nuclear Energy Agency of O.E.E.C. will be the construction of an experimental high-temperature, gas-cooled reactor at the U.K.AEA research establishment at Winfrith Heath. To be known as Dragon, the programme will run for five years and has been estimated to cost £13.6 million. Euratom, U.K., Austria, Denmark, Norway, Sweden and Switzerland will all share in the project with the majority of the cost being borne by the U.K. and Euratom. The U.K. will retain ownership of the reactor on conclusion of the project.

**PLANS FOR THE** European university as envisaged by Euratom have met with opposition from German universities. It is felt that a complete university is not needed but rather a scientific research institute with the status of a university.

**THE AMERICAN DELEGATION** to the Geneva conference on nuclear weapons, have proposed that all nuclear explosions used for peaceful purposes should be subject to the authority of an international control commission.

**RESEARCH CONTRACTS** are being placed by IAEA in Belgium, France and the U.S.A. for developing techniques for the non-destructive analysis of irradiated fuel elements.

**COUNCIL OF EUROPE** have announced that the theme for their first biennial thesis will be, "Consequences of the use of nuclear energy for the European mode of life." The first prize is one million French francs.

Three of the members of the Euratom Commission in London after the signing of the U.K.-Euratom agreement. From left to right they are: Dr. H. Krekeler (West Germany), M. P. H. de Groote (Belgium) and Mr. E. S. Sassen (Netherlands).

## United Kingdom

**WINDSCALE** is to have a new research reactor. Known as HERO (Hot Experimental Reactor of Zero power), it will cost about £1,250,000 and will be built near the AGR. The reactor has been designed to complement the work of the AGR and it will be possible to dismantle and rebuild it in several different ways. Fuel will include uranium oxide canned in beryllium.

**AN UNOPPOSED** second reading has been given the Nuclear Installations (Licensing and Insurance) Bill. In winding up the debate, Mr. Horobin, Parliamentary Secretary, Ministry of Power, pledged that the Government would look into the possibility of compensating victims of prolonged low-level irradiation.

**THE HALF-WAY STAGE** in the construction of Berkeley has been passed and at the present rate of progress, the station should be on full power during the winter of 1960-61. Nearly all the heavy construction work is completed and the welding on the vessel of No. 1 reactor is finished. In addition, the main gas ducting and piping and the boilers are in position. All the plate for No. 2 reactor is on site and three of the boilers are nearing completion.

**LOADING** of the sodium is in operation at Dounreay and it is expected that testing will soon be under way. The reactor is expected to go critical mid-April.

**CHAPELCROSS** will be officially opened on May 2 by Sir John Crabbe.

**CENTRAL ELECTRICITY** Generating Board propose to carry out detailed investigations of two areas on the central south coast at Earnley (West Sussex) and Hamstead (Isle of Wight) with the view to building nuclear power plants.

**TWO LEADING** British authorities on nuclear power, Professors W. Murgatroyd and J. M. Kay, will make a lecture tour of eight Latin American countries shortly.

**CHAIRMAN OF AEA,** Sir Edwin Plowden, has presented a cabinet containing a library of British films on atomic energy to Euratom on behalf of the Authority.

## Australia

**GAMMA-STERILIZATION** equipment for mohair treatment is to be installed by the Westminster Carpet Company.

## Belgium

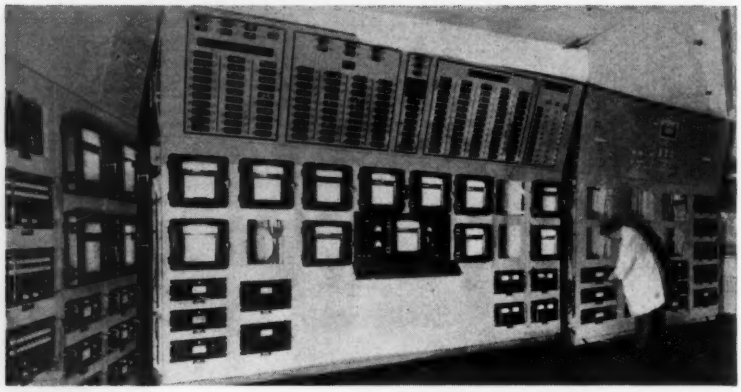
**PRESSURIZER FOR BR3** due to diverge in early 1960 has been completed by Alco Products. The 19-ton vessel is made from steel forgings clad with stainless steel by a welding-overlay process.

## Canada

**A 2 KILOTON** nuclear bomb will be used next year to test the value of nuclear explosions to release vast quantities of oil from tar sands off Northern Alberta. Dr. John Convey, head of Mines branch of the Government, has announced that the Richfield Oil Corp. will make the experiment.

**BY DOUBLING** her output of uranium concentrates last year, Canada displaced the United States as chief producer in the world with 13,537 tons. South Africa was third largest producer.

**EXTERNAL MINISTER** of Affairs, Mr. Smith, has said in the Commons that he is seeking to negotiate an agreement with Euratom on similar lines to the Euratom-U.K. treaty.



The reactor control panel for the new Danish materials testing reactor, DR3, built by Ekco Electronics. The equipment will be flown to Denmark for assembly in March. This is the second exportation of nuclear instrumentation by Ekco, the first being to Australia for the HIFAR reactor at Lucas Heights.

## China

**TWO GAMMA-RAY** units, costing $100,000, for the treatment of cancer, have been supplied by the Commercial Products division of Atomic Energy of Canada.

## Denmark

**THE DANISH AMBASSADOR** to England, Mr. M. Vincens de Steensen-Leth, visited E. K. Cole, recently to see a demonstration of the instrumentation for the DR3 research reactor. Ekco have done the complete control instrumentation for the reactor.

## France

**A NEW ATOMIC** study centre has been opened at Grenoble by M. Soustelle, deputy Prime Minister. The centre is linked with Grenoble University.

**FIVE OF THE SIX** Yugoslav nuclear workers who were seriously injured in a radiation accident in Belgrade, have been released from hospital in Paris, apparently cured. The sixth worker died shortly after arriving in Paris. The workers, who had been subjected to doses of between 700 to 1 000 rad were treated with bone marrow transfusions.

## Germany

**THE FIRST READING** of the Government's nuclear energy bill has been heard in the Bundestag, Bonn. The bill seeks to provide a legal basis for the development of nuclear energy for peaceful purposes. All parties were in complete unanimity to send the bill to committee.

**TEN MUNICIPAL** power companies have formed a company to run a 15 MW nuclear power station to be built by Krupps and the German subsidiary of Brown, Boveri. Estimated to cost more than £3 million, the station will be built near Jülich, near Cologne.

**A 10,000 HORSE-POWER,** nuclear reactor to power a tanker is to be developed at the estimated cost of between £1.25 and £1.67 million. The contract was recently concluded between the German Society for Atomic Energy Development and Interatom, a German company jointly owned by North American Aviation's Atomic International division and Demag of Duisburg.

**EXTENSIONS** to the research centre at Karlsruhe are estimated to cost more than £5 million.

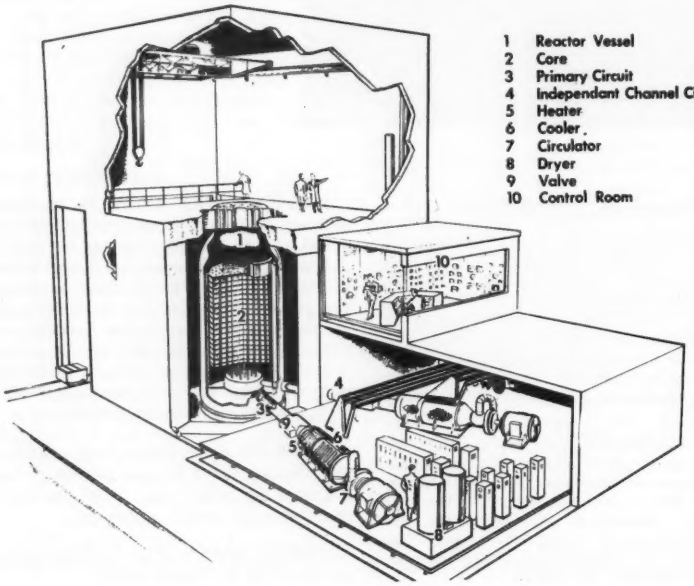
**THE LAND GOVERNMENT** and private companies have asked Siemens-Schuckert to design a 100 MW reactor for Bavaria.

**AN AGREEMENT** has been signed for Degussa to sell technical knowledge on the production of pure uranium to the Japanese concern Sumimoto.

## India

**THE DUKE OF EDINBURGH** visited the atomic energy establishment, at Trombay near Bombay, on his recent tour of the country.

**THE GOVERNMENT** are to establish a uranium mill capable of processing 500 tons a day in Bihar.




Artist's impression of the new Hot Experimental Research zerO energy reactor, HERO to be built at Windscale.

## Indonesia

**THE GOVERNMENT** has established an Atomic Energy Council to advise them on the development of nuclear energy in Indonesia and other countries. An Atomic Energy Institute for research has also been formed.

## Italy

**THE SIXTH** International Electronic, Nuclear and Cinematographic Exhibition will be held in Rome from June 16-30.

**A CONFERENCE** on industrial prospects in nuclear energy will be held in Stressa (May 11-14) by the European Nuclear Energy Agency of O.E.E.C. Purpose will be to evaluate the commercial prospects, probable markets and amount of investment needed for nuclear energy industries.

The new centre for nuclear studies at Grenoble which was formally inaugurated on January 26 by M. Jacques Soustelle, deputy Prime Minister of France.

## Japan

**THE CONTRACT** for a nuclear power plant, in response to tenders submitted by General Electric-Simon Carves Atomic Energy Group, A.E.I., John Thompson Nuclear Energy Group and English Electric-Babcock and Wilcox-Taylor Woodrow has not been signed yet. It is reported that the lowest tender, together with the cost of local expenditure, totals nearly a million pounds more than the £30 million originally estimated for the project.

## Mexico

**SIGNIFICANT QUANTITIES** of uranium have been found in the State of Chihuahua. Further exploration is at present being undertaken.

## Netherlands

**A NEW AGREEMENT** for co-operation in nuclear research has been signed with Norway. The agreement covers both of the two treaties previously signed. It contains provisions for the co-ordination of research in the two countries and for the exchange of data and information as well as regulations governing the ownership of inventions arising from joint research work.

## Norway

**THE CONSTRUCTION** of NORA—Norwegian Zero Energy Reactor Assembly by the Norwegian Institute of Atomic Energy at Kjeller, is hoped to be started by this summer. Plans are also under way for the building of a new reactor to relieve the original experimental one, JEEP. Kjeller will also be the home of a new isotope laboratory, expected to be completed early 1960.

## South Africa

**A PROPOSAL** for the construction of a heavy water plant, capable of producing more than 50 tons a year, has been suggested by the Atomic Energy Board. No official decision has been made yet, but it is likely that the Board will make an announcement after the recommendations of two representatives, Mr. A. R. Newby-Frazer and Mr. J. Colley, have been fully studied. Both men recently completed a year's study of heavy water production at Harwell.

**EXPORTS OF URANIUM** and thorium in 1958 amounted to a record sum of £53 million. During the past three years 16.227 tons of uranium valued at more than £133 million have been exported to the U.K., U.S.A. and Japan.

**THE COUNCIL** for Scientific and Industrial Research are to place their nuclear physics research facilities at the disposal of the Union's universities. This will mean that post-graduate students will be able to conduct research and receive guidance at the National Physical Research Laboratory at Pretoria. A special advisory committee, consisting of representatives of the C.S.I.R. and the Atomic Energy Board and each of the collaborating universities, has been established.

## Spain

**SPAIN'S PARTICIPATION** in the 12-country project for the building of a jointly owned chemical processing plant for nuclear fuels, has been approved by the O.E.E.C. Council. Spain will contribute the equivalent of $1.5 million. The plant, which will be at Mol, Belgium, is expected to start operation in 1961.

## Sweden

**ATOMENERGI A.B.** have submitted a budget request to the Minister of Finance for Kr. 161.6 million (£10.1 million) to cover work for the fiscal year.

**FIVE COMPANIES** in Britain and others in Belgium, France, the United States and Sweden have been asked by Atomenergi A.B. to tender for a 150 MW nuclear power plant to be completed by 1965.

**A GLOSSARY** of terms pertaining to nuclear science is being prepared by a committee constituted recently within the Swedish Centre for Technical Nomenclature. It will consist of Swedish terms with Swedish definitions but will also contain the corresponding terms in English, French and German. The work will be presented for ratification to the International Organization for Standardization.

**ROCK-BLASTING** for the underground reactor hall for the combined electricity process steam R3 Adam reactor plant at Ågesta, near Stockholm, is expected to be completed by the spring.

## U.S.S.R.

**PRESIDENT** of the Georgian Acadamy of Sciences, Nikolai Muskhelishvili, has said that the programme for the next seven years will concentrate on nuclear energy research. A reactor in Tbilisi will go into operation in 1960.

Members of a Russian Trade and Scientific Mission on a recent visit to the U.K. where they saw some of the latest nucleonic equipment at Plessey Nucleonic's Northampton works.

# U.S.A.

**A BUDGET** of $2,669,500,000 for AEC for the fiscal year 1960 has been called for by President Eisenhower. This represents an increase of $215,284,000 over the 1959 total and is the largest budget in AEC's history. the figure of $739,600,000 for the procurement of raw materials accounts for the largest single increase ($42,648,000 over 1959). During 1958 the cost of operations, including depreciation totalled $2,299 million which represented an increase of $380 million over 1957. Substantial reductions in the unit cost of materials produced were made in 1958, however.

**PIQUA ORGANIC** moderated and cooled reactor project is to go ahead on a new site the AEC has announced. The containment of the reactor is to be strengthened over original design.

**1959 NUCLEAR CONGRESS** begins on April 5 in the Public Auditorium, Cleveland, Ohio. Included in the congress will be an Atomfair.

**HIRE-PURCHASE** terms have been announced for fuel for reactors to countries having nuclear co-operation agreements with the U.S.A. The plan will be restricted to generating installations with a combined capacity up to 500 MW and the plants must be in operation by June 30, 1964. They should also be of basic U.S. design and incorporate a substantial portion of American-made parts.

**THE NUCLEAR SUBMARINE** *Skate* has been involved in a minor accident with a conventional submarine off the east coast of the U.S. The *Skate's* port propeller was scraped and damaged.

**NATIONAL ANNUAL MEETING** of the American Nuclear Society and the Health Physics Society will be held at Gatlinburg, Tennessee, in June.

**THE CONTRACT** for radiochemical analysis during the start-up period of the nuclear-powered submarine *Triton* has been awarded to Controls for Radiation of Cambridge, Mass.

**NATIONAL ACADEMY** of Sciences proposes to conduct a 10-year survey of two million Americans for the purpose of finding out more about the pathological effect of radiation.

**DEVELOPMENT** of a capsule containing several uranium impregnated graphite samples to be subjected to irradiation will be undertaken by Nuclear Developments. The tests will be carried out in the Materials Testing Reactor at Idaho Falls.

**NORTHWESTERN UNIVERSITY** Technological Institute will accelerate its nuclear engineering study programme as a result of a further grant from AEC. Grants now total $90,000.

**SNAP 3**—a "proof of principle" device developed by the AEC—is capable of converting into electricity the radiation emitted by ¼g of radioactive material. SNAP 3 weighs 5 lb and is 4¼ in. diameter and 5½ in. high. The radiation from 3,000 c of polonium 210 is converted directly into electricity by means of thermoelectric materials; output is about 5 W.

**THE GENERAL ELECTRIC** Test Reactor (GETR), which will be used mainly for irradiating test fuel elements, has gone critical. The 3-ft-long core of the reactor is contained in an aluminium pressure vessel submerged in a pool of ordinary water with controls mounted on the bottom, allowing the upper portion of the reactor to remain relatively unobstructed for experiments and fuel access. The reactor is in a pool of water 9 ft in diameter and 31 ft deep. Cost of construction was approximately $4 million.

**REACTOR PRESSURE VESSEL,** 20 ft in diameter and weighing 300 tons, for the Dresden power station in Illinois, is being shipped 3,600 miles by barge from the New York Shipbuilding Corporation's yard at Camden, New Jersey.

**A PUBLIC HEARING** on the application by Industrial Waste Disposal Corporation of Houston for a licence to collect low-level radioactive wastes from other licensees for disposal in the Gulf of Mexico, is to be held.

**A 5MW** nuclear powerplant to be connected to General Public Utilities' existing turbine generator unit at Saxton, Pennsylvania, is to be built by Westinghouse. Scheduled for operation mid-1961, the reactor will be a pressurized water type.

**CONTRACT** for the manufacture of fuel elements for the Army's Package Power Reactor-1, has been awarded to Sylvania-Corning. The plant is at present located at Fort Belvoir.

**FIFTY-FOUR** nuclear scientists and engineers, representing 19 countries, have started a 20-week course on the peaceful uses of nuclear energy at the Argonne National Laboratories.

**AEC** have signed a contract with Carolinas Virginia Nuclear Power Associates for a demonstration nuclear powerplant at Parr, South Carolina. The heavy water-moderated, pressure tube-reactor will be fuelled with slightly enriched uranium. Estimated output: 17 MW. It is expected to cost $22 million.

A small size sub-critical reactor which will be supplied to the University of Texas by Lockheed Aircraft. The picture shows a uranium core about to be inserted into the polyethylene reflector.

**A PRIVATE GROUP** has been formed to produce a nuclear-powered merchant ship. The group comprises The Ford Instrument section of Sperry Rand, the Isbrandtsen shipping company and Maryland Shipbuilding and Drydock. The group plan to have the reactor system ready for testing in less than three years. It is expected that $5 million will be spent on development and $10 million for tests and building.

The core of AEC's Engineering Test Reactor as seen through a small glass window in the top cap of the pressure vessel during operation. Twenty-two feet of water shields the camera from the core.

# *Personal*

Sir William Penny.

Sir Alan Hitchman.

Mr. R. E. McAlpine.

Dr. T. H. Osgood.

## Appointments

**Sir John Cockcroft,** AEA member for research, as Master of the new Churchill College at Cambridge. He will take up his new appointment some time in 1960. The first buildings of the college are expected to be completed in October, 1961. Sir John's duties will be taken over by **Sir William Penny.** As Sir William is, at present, AEA member for weapons, it appears likely that he will relinquish that position in due course.

**Sir Alan Hitchman** as a full-time member of the AEA. Formerly Permanent Secretary, Ministry of Agriculture. Sir Alan succeeds **Mr. W. Strath** who is to be the new Permanent Secretary, Ministry of Supply.

**Mr. R. E. McAlpine** succeeds the late **Sir Claude Gibb** as chairman of the Nuclear Power Plant Company.

**Mr. H. C. Davey** as personal adviser to **Sir Leonard Owen,** managing director AEA's industrial group. **Mr. T. Tuohy** succeeds Mr. Davey as works general manager of Windscale and Calder Hall.

**Mr. R. D. Gardiner,** formerly associated with the industrial group of AEA, as assistant chief contracts officer of the Central Electricity Generating Board. Other C.E.G.B. appointments are: **Dr. J. A. L. Bonnell,** nuclear medical officer and deputy to the chief nuclear health and safety officer; **Dr. S. Jones,** director of research and development (electrical); **Mr. H. R. Niven,** regional accountant (Midlands); **Mr. H. N. Wilson,** regional secretary (East Midlands).

**Mr. H. W. Kirby** to the board of Thos. Firth and John Brown.

**Mr. D. Bruce** as deputy chairman of Associated British Engineering.

**Mr. D. Halford** as progress officer for capital expenditure; **Mr. M. Braine** as general manager, central administration;

Mr. T. Tuohy.

Mr. H. C. Davey.

**Mr. C. Borg** as general manager, personnel services and **Mr. B. Bonfield** as assistant secretary of Associated Electrical Industries. Mr. Bonfield also becomes secretary of A.E.I. John Thompson Nuclear Energy and secretary, A.E.I. Divisional Management.

**M. E. Hirsch** succeeds **M. L. Armand** as new president of Euratom.

**Vice-Admiral Sir John Eaton** as chief of administration at the research and development laboratories of Marconi Wireless Telegraph.

**Mr. W. F. Cartwright** to the board of Davy and United Engineering.

**Mr. I. W. Smith** to the board of Morgan Crucible.

**Mr. S. G. Catto** and **Mr. R. N. Millar** to the board of General Electric Company.

**Mr. P. G. Smyrk** to the board of Johnson, Matthey.

**Mr. A. Brown** as assistant sales manager of Dewrance.

**Mr. J. M. Story** as vice-chairman of the Council of British Manufacturers of Petroleum Equipment.

**Mr. J. Bennet** as general manager of A. Reyrolle. **Mr. W. B. Fenwick** to the board of the same company.

**Mr. F. W. Gardner** as chairman of C. A. Parsons.

**Mr. D. D. Morrell** to the board of Mitchell Engineering.

**Mr. R. H. B. Nicholls** to the board of Dowty Hydraulics Units.

**Mr. F. H. Spurling** as Press relations officer of E. K. Cole.

**Mr. H. West** as assistant managing director of Metropolitan-Vickers Electrical. **Mr. A. D. Jacklin** as chief inspector and **Mr. W. H. Brodie** as assistant chief inspector of the same company.

**Mr. M. Soffa** to the board of Jeltex.

**Mr. C. M. W. Thomas** as commercial director and **Mr. A. C. Risbridger** as general manager of Klaxon.

**Mr. C. R. Jones** and **Mr. P. K. Richards** to the board of John Thompson Water Tube Boilers.

**Air Marshal Sir Raymund Hart** as director of the Radio Industry Council.

**Dr. T. H. Osgood** as science officer, United States Embassy, London.

**Mr. A. J. Gibbons** as technical sales director of Yorkshire Electric Transformer.

**Professor J. Edwards** as Professor of Nuclear Science and Technology at the Royal College, Greenwich.

**Mr. D. Halford** as progress officer for capital expenditure, A.E.I.

**Lt.-Col. J. P. Flowerdew** as production manager of Servomex Controls.

**Mr. R. C. Pearse** as president and to the board of Canadian Vickers.

**Mr. R. A. Bent** to the board of Lancashire Dynamo Holdings.

**Mr. N. M. Clark** as chief engineer of Power Jets (Research and Development).

**Mr. C. E. Walters,** general sales manager; **Mr. R. Lloyd,** sales manager, scientific and industrial products; **Mr. J. M. Anderson,** sales manager, pneumatic instruments; **Mr. W. J. Donnelly,** sales manager data processing and **Mr. E. C. Bird,** manager, contracts section of Sunvic Controls.

**Mr. E. C. Cole** as president of Vitro Uranium, Salt Lake City, U.S.A.

**Mr. A. Squire** as manager of the new materials department at Westinghouse Electric, Bettis Atomic Power division.

**Mr. A. V. Hooker** and **Mr. W. L. Day** as partners in W. S. Atkins and Partners.

**Field-Marshal Lord Harding** to the board of Micanite and Insulators. **Mr. J. P. Corkhill** as works manager and **Mr. G. R. Harris** as purchasing manager of the same company.

**Mr. F. B. Strachan** as managing director; **Mr. F. Baden,** works manager in London; **Mr. C. W. Hay,** works manager, Port Glasgow; **Mr. A. E. Lockley,** works manager, Huddersfield; and **Mr. R. F. Burke,** works manager, Midlands plant of Fescol.

**Mr. A. M. R. Sylvester** as secretary of the British Metal Corporation. **Mr. M. K. James** becomes accountant of the Corporation.

**Mr. R. E. Cryor** as president of Cape Asbestos (Canada).

**Mr. G. Buckland-Smith** as joint managing director of Greenpark Productions.

**Lord Cunliffe** to the board of London Electrical and General Trust.

## Personal—contd.

**Maj.-Gen. A. E. Walford** as chairman of the board, Canadian-Vickers.

**Mr. J. E. T. Haile** to the board of Rank Precision.

**Mr. J. C. Robertson** to the board of Glenfield and Kennedy.

**Mr. G. Taylor** and **Mr. J. D. Eccles** to the board of Head Wrightson Steel Foundries; **Mr. R. B. W. Bolland** to the board of Head Wrightson Colliery Engineering and **Mr. R. O'Brien** to the board of Head Wrightson Stockton Forge.

## Retirements

**Mr. R. E. Wilson,** managing director of Fescol since 1941.

**Mr. G. Helps,** joint managing director of Humphreys and Glasgow.

**Mr. J. Woolman,** manager of Brown Firth Research Laboratories and director of Thos. Firth and John Brown, after 39 years' service.

**Mr. H. A. Cooper,** general manager; **Mr. D. J. Greene,** works manager of Micanite and Insulators.

## Tours

**Sir David Eccles,** president of the Board of Trade, to South Africa from March 15 to 26. He will open the Rand Easter Show in Johannesburg on March 21.

**Mr. A. H. Woodley,** sales manager of Keith Blackman, to the U.S.A. and Canada.

## Awards

**Mr. H. G. Nelson,** managing director, English Electric, has been awarded the Benjamin Franklin Medal for 1959 by the Royal Society of Arts.

## Obituary

*Nuclear Engineering* record with regret the death of the following personalities:—

**Mr. J. O. Lucas,** a director of Joseph Lucas, at the age of 36.

**Professor A. Duperier** in Madrid at the age of 62. Prof. Duperier has been a leading Spanish authority in nuclear physics for some time.

**Mr. J. Brook,** works director of Dewhurst and Partner, at the age of 60.

# Industrial Notes

**Rolls-Royce and Associates** is the name of a new registered private company with a nominal capital of £250,000 in £1 shares. The aims of the company are to carry on a wide range of activity in nuclear engineering. **Rolls-Royce** hold 52% of the shares and **Vickers** and **Foster Wheeler,** 24% each.

The theme of the eleventh **British Electrical Power Convention** (Torquay, June 1-5) will be "Electricity and its contribution to the tandard of living."

**Sunvic Controls** have moved to Crown House, Aldwych, London, W.C.2. Tel.: Temple Bar 8040.

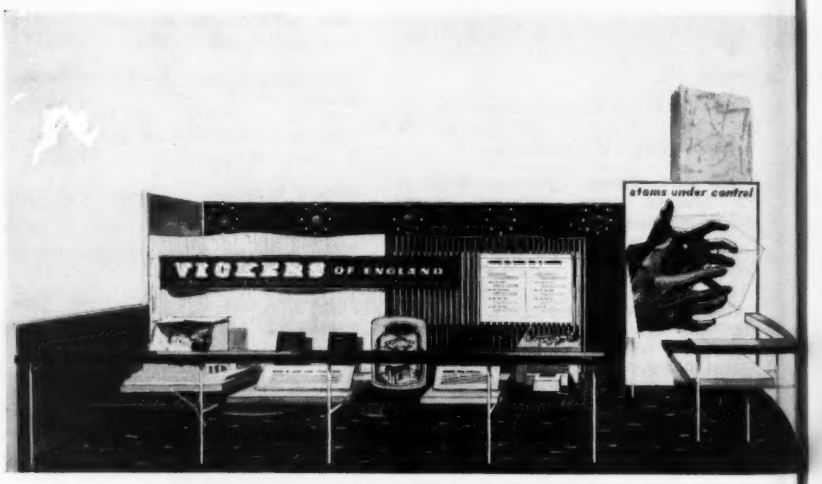
**International General Electric** have established a subsidiary company in Geneva, Switzerland.

**Controls for Radiation** have been awarded the contract for all nuclear radiation protection services required by the Air Force Cambridge Research Centre, Massachusetts, U.S.A.

**Micro Methods** (East Ardsley, Wakefield, Yorkshire) are to microfilm "Nuclear Engineering." Cost of a microfilm edition will be £6 per annum. All back numbers can be made available.

**"Power from the Atom"** will be the theme of the Board of Trade display at the Rand Easter Show in Johannesburg this year. The display will be located in the new United Kingdom Pavilion and will include a model of Calder Hall. All commercial space on the Pavilion has been let to the South African Committee of the British Electrical and Allied Manufacturers' Association. They will be reproducing large sections of the B.E.A.M.A. Brussels exhibition display showing British contributions to the development and use of nuclear power, hydro-electric power and conventional power generation.

Following their increasing interest in specialized fields of nuclear engineering, **Saunders-Roe** and **Nuclear Enterprises** have formed a new jointly owned company, **Saro-Nuclear Enterprises** with head office in London. The company will deal mainly with applied irradiation and the application of isotopes to industrial processes.




The Vickers Group is believed to be the only British exhibitor at the U.S. Atomfair, Cleveland, Ohio, from April 5 to 10. Three companies in the group will be represented—Vickers-Armstrongs (Engineers), Vickers Group Research, and Vickers-Armstrongs (Aircraft) South Marston Works.

**Central Electricity Generating Board** announce a record power demand, 20,900 MW on January 14.

**The International Atomic Energy Agency's** handbook, *Safe Handling of Radioisotopes*, is now available from headquarters at Kärtner Ring, Wein 1, Austria.

**E.M.I.** are to supply AEA with their new electronic photographic enlarger. The equipment has entirely eliminated guesswork and the operating skill normally required to produce high-quality enlargements.

**The Owen Organisation** has recently formed a new division to co-ordinate the group's extensive facilities for the design development and manufacture of equipment for nuclear engineering. Already many of the Owen companies—including Rubery, Owen (Darlaston), Rubery, Owen (Warrington), C. and L. Hill, Brooke Tool, Mechanair, Motor Panels, Rowenarc, Invicta, Electro-Hydraulics and Conveyancer Fork Truck—have made individual contributions. Inquiries should be addressed to The Owen Organisation, Group Atomic Energy Office, Liverpool Road, Warrington, Lancs.

**Savage and Parsons** are to supply **Negretti and Zambra (South Africa)** with a pair of master slave manipulators for display in their "hot cave" demonstration at the Rand Easter Show.

Advanced medical courses organized by the **British Council** this year, will include one on radioactive isotopes. This course opens in Sheffield on September 20.

**Mallinckrodt Chemical Works** of the E.S.A. have formed a separate company, **Mallinckrodt Nuclear Corporation** to take over the production of nuclear fuel.

**The International Plastics Exhibition** will be held at Olympia on June 17-27.

The **Windsor Group** have moved their offices to 76 Jermyn Street, London, S.W.1.

**High Duty Alloys** have opened a new Midland sales office at Queen's College Chambers, 38a Paradise Street, Birmingham, 1. Tel. Midland 3286.

**Lang Pneumatic** have moved their offices to Owen Road, Wolverhampton. Tel. Wolverhampton 25221.

**IBM World Trade Laboratories**, of New York, have formed a subsidiary company, **IBM World Trade Laboratories (Great Britain)**, with offices at 57 Duke Street, Grosvenor Square, London, W.1. Tel. Mayfair 7377.

**Metropolitan-Vickers Electrical** are to supply a 40 MeV electron linear accelerator to Deutsches Elektronen Synchrotron (D.E.S.Y.) research group in Hamburg, Germany. The order is worth £250,000.

**British Insulated Callender's Cables** branch office in Derby have moved to Hartington Street. Tel. Derby 41421. The company have also opened new offices at Station Terrace, Queen Street, Cardiff.

**Davy, Paxman** have announced new ranges of air-cooled diesel engines (Vega) from 200 to 466 h.p. and an extension of their range of lightweight high-performance engines in excess of 1,000 h.p. (Ventura).

The **Geigy Co.** of Manchester, announce that, following experiments in conjunction with AEA on the behaviour of plasticized polyvinyl chloride under intense gamma radiation, their product TXP (trixylyl phosphate) compares with the behaviour of TTP (tritolyl phosphate) in respect of radiation resistance.

Fifty manufacturers from ten different countries will be exhibiting at **B. and K. Laboratories,** International Instrument Show at 4 Tilney Street, Park Lane, London, W.1, on April 6-10.

A new company, **Griffin and George (Research and Development)** has been formed by the Griffin and George Group for research and development on scientific instruments and apparatus for laboratory use and process control.

**I.C.I.** has brought into operation a large-scale development plant for the manufacture of high-quality silicon of semi-conductor grade.

**R. F. Fraser-Smith,** of 69 King's Cross Road, London, W.C.1, a new company in the radiographic and accessories field, intend to specialize in gamma equipment.

**Graviner Manufacturing** have formed a new company in Germany, **Deugra Gesellschaft fur Brandschutzsysteme** in Dusseldorf to look after their interests in that country.

The **United Kingdom Trade and Industrial Mission** to Ghana will be represented in nuclear energy matters by Mr. Bryan Donkin of Kennedy and Donkin, the consulting engineers.

**Steel and Co.** of Sunderland have made an offer to buy the whole of the ordinary stock of **R. H. Neal,** makers of mobile cranes.

Sir John Wrightson, vice-chairman and managing director of Head Wrightson, on a visit to Harwell to see the 10 MW research reactor PLUTO for which Head Wrightson Processes were main contractors.

A new extension to the **Wakefield-Dick's** laboratories at Hayes has been opened.

**Star Aluminium** have opened a new laboratory at Wolverhampton, mainly for the development of new uses for aluminium foil.

Nineteen papers by British authors will be presented at the fouth **International Congress** on electro-heat in Stressa, Italy, on May 25-29.

**The Electrical Development Association** will feature electronics as a key to automation at the Electrical Engineers' Exhibition, Earls Court, March 17-21.

## Meetings

**March 3**—Institute of Marine Engineers (Memorial Building, 76 Mark Lane, London, E.C.3, at 5.30 p.m.). Joint Panel on Nuclear Marine Propulsion: "Metallurgical Problems related to the Nuclear Propulsion of Ships," Dr. H. M. Finniston.

**March 4**—Institution of Chemical Engineers (Midlands Branch, Birmingham College of Technology, Gosta Green, Birmingham). "Reynolds' analogy and mass transfer," Prof. F. H. Garner, V. G. Jenson and R. B. Keey.

**March 5**—Institution of Electrical Engineers (College of Technology, Gosta Green, 6 p.m.). Discussion on "Nuclear Technology and the Electrical Engineer," opened by J. Walker.

**March 6**—Institute of Marine Engineers (Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 7 p.m.). "Energy from the Atom," Professor C. F. Powell.

**March 9**—Institution of Electrical Engineers (Nevill Hall, Westgate Road, Newcastle upon Tyne, 6.15 p.m.). "The Design of Electro-Mechanical Auxiliaries directly associated with power-producing Reactors." A. E. Harwood, P. Scott and B. H. Stonehouse.

**March 10**—Institution of Chemical Engineers (North Western Branch, Chemical Eng. Building, Manchester College of Science and Technology, Jackson Street, Manchester). Symposium on Fluidization.

**March 11**—Institution of Electrical Engineers (Demonstration Room, Southern Electricity Board, 37 George Street, Oxford, 7 p.m.). "Zeta," R. Carruthers.

**March 11**—Institution of Electrical Engineers (The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2, 7 p.m.). "Electrical Installation at Calder Hall Nuclear Power Station." N. J. Mackay and E. Hardwick.

**March 12**—Institution of Electrical Engineers (S.W.E.B. Showrooms, Bedford Street, Exeter, 3 p.m.). "Germanium and Silicon Power Rectifiers," T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell.

**March 12**—Liverpool Metallurgical Society (Dept. of Metallurgy of the University of Liverpool, 146 Brownlow Hill, Liverpool, 3). "The Rare Metals used in Atomic Energy Applications," L. R. Williams.

**March 12**—I. O. Welding (54 Princes Gate, S.W.1). "Welding and the Nuclear Energy Programme," Sir L. Owen.

**March 13**—Institution of Marine Engineering (Birmingham Exchange and Eng. Centre, Stephenson Place, Birmingham, 7 p.m.). "Energy from the Atom," C. F. Powell.

**March 13**—British Nuclear Energy Conference (Central Hall, Westminster, S.W.1). Lecture Symposium. "Geneva, 1958."

**March 17**—Institution of Electrical Engineers (Savoy Place, London, W.C.2, 5.30 p.m.). "Electrical Uses of Atomic Spin," G. Phillips.

**March 17**—Institution of Electrical Engineers (Bath Technical College, 6.30 p.m.). "Electrification of the U.K.A.E.A. Industrial Group Factories," J. W. Binns and W. J. Outram.

**March 17**—Institution of Electrical Engineers (Engineers' Club, 17 Albert Square, Manchester, 6.15 p.m.). "Electrical Installation at Calder Hall Nuclear Power Station." N. J. Mackay and E. Hardwick.

**March 17**—Institution of Chemical Engineers (Church House, Westminster, S.W.1). "Methods of improving heat transfer from condensing steam and their application to condensers and evaporators," etc.

**March 19**—Society of Chemical Industry (Chemical Eng. Group) (Nottingham and District Technical College, Burton Street, Nottingham). "The Extraction of Thorium," W. D. Jamrack, R. A. Wells and Dr. J. H. Buddery.

**March 25**—Institution of Electrical Engineers (The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2, 7 p.m.). "Thermonuclear Fusion and the Development of Zeta," E. R. Hartill.

## Catalogues

**Degussa** outline their production methods for nuclear fuels in an attractive booklet. (Weissfrauenstrasse 9, Frankfurt (Main), Germany.)

**The APV Company** have illustrated their A.340 APV Paraflow plate heat exchanger in a four-page leaflet. (Manor Royal, Crawley, Sussex.)

*The Hilger Journal* (Vol. V, No. 2) includes an article on spectroscopic measurement of very high temperatures in the research reactor, Sceptre, at Aldermaston. (98 St. Pancras Way, London, N.W.1.)

The December issue of the *Glenfield Gazette* contains an article on **Glenfield and Kennedy** single-faced sluices for power stations. (Kilmarnock, Scotland.)

**Nuclear-Chicago** have published a brochure describing the evaluation of mixing techniques using radioactive tracers. (223 West Erie St., Chicago 10, U.S.A.)

The February issue of the *De Havilland Gazette* contains an article on gas circulators and control valves for radioactive gas circuits.

**The Beckman-Berkeley** East 1100 series of computers, are fully described in a new catalogue. (Winston Electronics, Shepperton, Middlesex.)

# *Orbits in Industry*

**Those envelope backs**

It has always struck us that there was a great future awaiting the chap who took the trouble to collect the backs of envelopes. Not of course those grubby frayed objects that drop out of our own wallet when we are trying to find a visiting card that doesn't have somebody else's name on, but those invaluable jottings that decide the fate of nations and the designs of new reactors. We were reminded of this at the recent Fuel Cycle Symposium, when Dr. Dunworth recalled that it is some 10 years since Dr. Buneman rushed into his office waving such a manuscript on which he had made the calculation that should we ever get to the stage of building gas-cooled graphite-moderated natural uranium power stations, a burn-up of about 3000 MWd/t could be expected. It was pointed out later in the meeting that the estimated error on this figure was −3000 +22000, but this was a verbal message and would not have been recorded.

It is perhaps a salutary thought that after 10 years of intensive development and research we are still only in a position to estimate 3000 MWd/t and have still no direct experimental evidence on the subject. But herein lies the real value of envelopes. There is not sufficient room, particularly when the flap's come loose, either from experimentation or complex calculations, which so often proves less exact than the hunch.

**Flying Service**

It's always a comforting thought when the supplier of a bit of equipment to which you are doing the odd mod. (which will almost inevitably cause irrevocable damage) happens to have his works just the other side of town—that is unless the town happens to be London of course. Crossing London by road during working hours has become such a nightmarish and tedious business that unless the job can be got to on foot with light portable equipment, it is hardly worth setting out. In fact, you are probably better off down under, where Austronic Engineering has been operating an emergency airborne service department for some time (which must add a little spice to the usually unenviable lot of the poor trouble-shooter). The Flying Doctor—not to be confused with the present Chief P.R.O. (U.K.)—is a familiar symbol of life in the Australian outback, and it is a logical development in this scientific age that the beleagured prospector (not to mention the mines and factories in less remote areas) should be able to get the same high speed attention to his counting equipment, that he has come to expect when he is crook himself.

**The 1959 "Faraday"**

"What's the blooming use trying to compete with computers? By the time I've finished my finals they'll have computers interviewing us blokes for jobs." The student bent a gloomy gaze on his companion and the Festival Hall's incomparable acoustics carried his gentle murmurings across the hushed audience. An audience hushed with minds, uncomputerlike, assimilating the few simple facts that, to some, must have seemed ominous and even frightening . . . "Fourteen men produce 90% of all electric bulbs made in the United States by pushing buttons." . . . "Computers are nothing more than fast-thinking morons," consoled the second student. "Suppose we could always become computer cleaners or the man wot pushes the button or something" (No. 1 again). "Perhaps we could become computer manufacturers!" Hope bubbled forth from the lips of No. 2.

After bouncing tennis balls and rolling coloured discs with a precision that would have brought tears to the eyes of Lew Hoad and Joe Davis this year's admirable Faraday lecture finished on the warning note . . . Britain must compute to compete.

Moronic or not, computer techniques are already making a great contribution in the data processing field, which is going to be of increasing importance in fuel element production, operation and post-irradiation examination. The information has still to be collected but once available, the computer will sort it and tell you what matters and having just waded through a mountain of Buyer's Guide material we know just how much that counts.

**At the Double**

Sitting in the dining room of an out-of-the-way hotel in the depths of the country at Sunday lunch-time does give one the feeling that perhaps the traditional criticism of "service" has not been exaggerated. We did find the solution the other day when we were constrained to introduce a somewhat irrepressible junior relative into such an establishment. No amount of parental tut-tutting would drown the angry yells each time a plate of food appeared and was not placed immediately in front of him. Needless to say, although last in, we were first out. All of which goes to show you can get service if you really insist—which brings us to the point we started off to make, that the AEA when looking for new sub-contractors has this very firmly in mind.

We were reminded of this, too, when talking to a senior member of a company which in a relatively short space has built up an important nuclear contract side to its business. They were in a position to make available their best designers when the first approaches were made and able to beat the short delivery times that they were quoted. This clearly had a profound effect on future relations and has led to a progressive increase in business. First jobs can often be rather tiresome and time-consuming but an intensive effort usually pays dividends in the end.

There's a great deal in this psychology business, too. It's no good rushing in and saying "We know a much better way of doing this"—even if you do, because nobody likes being told they don't know what they're at. We're all experts, of course, on politics, cricket, publishing—even economics—but that's not quite the same as engineering design.

**DR. FINAGLE'S LAWS—9**

(Note: See also "Laws governing natural perversity of inanimate objects.")

**Law of Tank Space**

Irrespective of original layout, water tanks in tank rooms will eventually fill all available space.

**Law of Stanchions**

Stanchions: Any intermediate beams taken as providing restraint will be removed.

**Corollary I**

Law 1 as applied to stanchions: Direct stress 40%, combined stresses 80%.

**Expertise**

When first they formed the AEA
To push the "natural" graphite mods,
They clearly could not then gainsay
The need for some commercial bods
Especially for sales abroad
To tie up various ends and odds
And generally create concord.

But now we think of AGR's
Steam cooling, $D_2O$,
And futuristic DFR's
To give the programme zip and go
And satisfy the general wish
For a chap
Who's got the know*
Try the Min.
of Ag.
and Fish.

* Includes:
k—how
—when
—where.

Co-Tangent

# Remote Sealing of Evacuated Capsules

By J. P. EVANS and M. B. WALDRON
(*A.E.R.E., Harwell*)

FOR many metallurgical investigations it is necessary to heat-treat samples without atmospheric contamination, often following with an effective quench to retain the high temperature structure. With reactive metals this may be done in an inert atmosphere or under vacuum. Glass and silica capsules are commonly used to protect the sample so that an effective quench can be obtained by breaking the capsule.

Heat treating an α-active material requires special care to avoid spread of activity or risk of fire. The extreme radioactive toxicity of plutonium makes it desirable to devise special techniques for sealing up samples in capsules in a glove box. It is not possible to use gas flames for heating, partly because of the inert atmosphere in the box and partly for safety reasons. It has, therefore, been decided to use carbon arcs.

The capsule design is shown, inset, in Fig. 1. The outer case and inverted cap are preformed by normal glass-blowing techniques, a thick-walled capillary providing a connection to a vacuum-system and a convenient point for final sealing off. An open end of the full diameter is necessary for inserting the sample after introduction into the glove box. It would be difficult to draw down tubes of this diameter by remote handling techniques, and sealing on to a close-fitting glass rod is unsuitable for sizes above ¼-in. diameter.

With the inverted cap design an annular weld can be made with a small heat input. The cap is made sufficiently long to avoid overheating and contaminating the specimen while enabling a thermocouple to be located close to the latter. Temperature rises of around 70°C have been noted but can be reduced by aluminium radiation shields.

Capsules are made of hard glass for low temperatures (<600°C), of aluminosilicate glass for intermediate temperatures (600°C-850°C) and of silica for high temperatures.

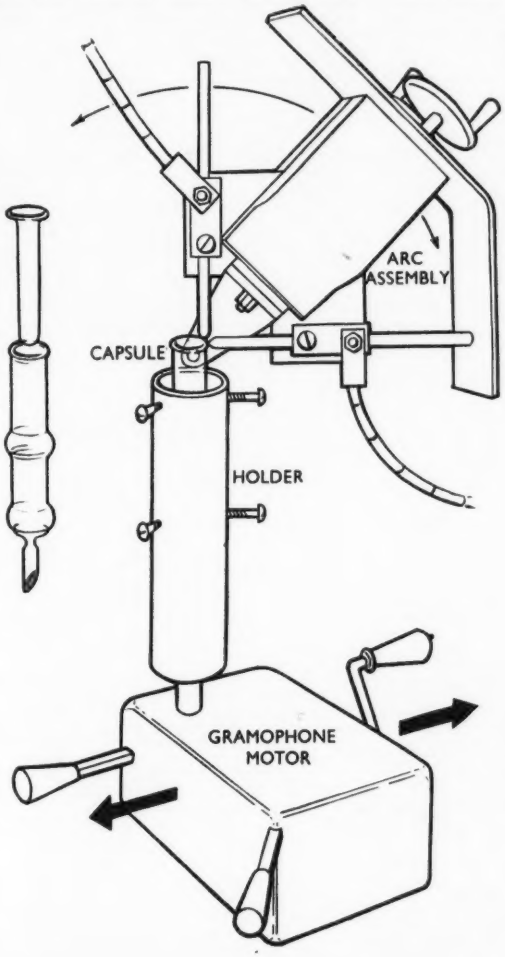



Fig. 1.—Equipment for peripheral welding. On the left can be seen the capsule prior to welding.

**Acknowledgments**

The authors wish to acknowledge the help and advice of several colleagues, especially A. G. Ashburn and W. T. Smith, for the design of the equipment; H. J. Morris in connection with design and manufacture of capsules, and J. C. Woodmore and J. A. C. Marples for help in early experimental work.

An argon-filled glove box contains the two carbon arc arrangements. In both of these the carbons can be adjusted separately or together. The whole assembly moves relative to the capsules in the same plane as the carbons. The arrangement for the peripheral welds is shown in Fig. 1. The movement of the arc assembly is in the vertical plane and the whole assembly pivots about the point where the carbons meet. Beneath the carbons, the capsule is held in a stainless steel tube and centred by two sets of screws. It is turned by a gramophone motor equipped with two gears and a neutral position. A gramophone motor avoids the complication of electric wiring with its attendant fire risks in argon, but has the disadvantage that it may need winding at an inconvenient moment.

The arc assembly for the capillary welds is similar, but moves in the horizontal plane and does not pivot. The capsule is connected to the vacuum system by compression of a rubber ring and the connector is turned through a revolving seal. The lower end of the capsule has weights attached by two Terry clips fixed on a self-centring guide. The guide falls against the cushioning action of a weak spring and supports the capsule after it is sealed. A simple ethylene glycol leak-testing attachment to the vacuum system checks the capillary weld. The vacuum system consists of a backing pump, diffusion pump, pirani gauge and ionization gauge. Valves are so arranged that the capsule can be evacuated from atmospheric pressure down to backing pump pressure with the diffusion pump isolated.

Power for the arcs is supplied from a welding transformer. The peripheral weld in Pyrex glass needs 20 amp and the capsule is rotated at 20 r.p.m. The arc approaches the glass slowly; welding takes 2-3 minutes, and then the arc is slowly moved away allowing slow cooling. Examination with a polarized light viewer has revealed no strains in capsules thus sealed. Silica capsules need 40 amp and are rotated very slowly, once only, directly in the arc; heating and cooling rates are unimportant. The capillaries are welded similarly but need only 10 and 20 amp respectively. It is interesting to note that filling the box with argon doubled the current required.

The apparatus which is described more fully in *A.E.R.E. Report* M/M 160 has been operated successfully with glass and silica capsules as a routine preparation for heat-treatment under vacuum. In the authors' view, where remote operation is required, routine sealing of evacuated capsules is most safely performed in a device of the kind described, with very little attendant inconvenience.

# Processes and Equipment

For further information on any item please enter the relevant number on the Reader Service Card enclosed with this issue and forward the card to the address given.

## Cobalt Therapy Treatment

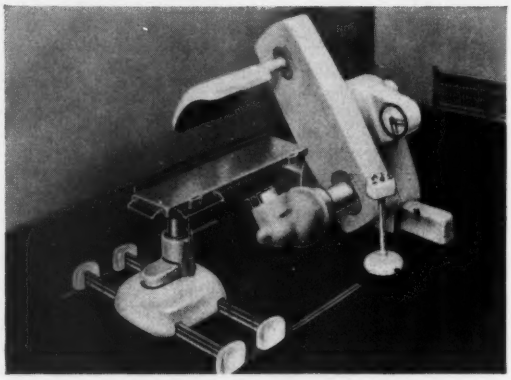
In collaboration with the radiotherapy department of a Leeds hospital, the Hunslet organization has now designed and marketed a series of radioactive cobalt therapy treatment units. The first of these is a stationary unit which allows for the setting up of all types of static field, given the universal movement of a standard couch. The head has two movements: powered elevation/lowering, and hand-operated angular turning of the diaphragm head. The standard machine has a source housing which can accommodate British, Canadian or American sources. Also incorporated is a patent multi-leaf adjustable diaphragm, a valuable time saver when setting up.

Alternatively there is a moving field unit which is suitable also for stationary field work, as the head can also be elevated or lowered on the rotational carrying arm. Correct source to skin distance settings can therefore be easily obtained.

The speed of rotation is infinitely variable in the range 0.2 to 2.0 r.p.m. Arc therapy can be set, in steps of 10 degrees, up to a maximum of 360 degrees with automatic reversal. The equipment includes a special treatment table with three movements, i.e., longitudinal and cross travel, also powered elevation and lowering actuated from the pedestal control column inside the treatment room. There is a beam absorber on the carrying arm, opposite the isotope carrying head, to enclose fully the projected primary beam when the machine is used for treatment purposes.

*(Hunslet Precision Engineering, Ltd., 125 Jack Lane, Leeds, 10.)*

**1180**



Radioactive cobalt therapy treatment unit by Hunslet Precision Engineering. The head of this equipment can be moved through 360°.

## Ground Contamination Monitor

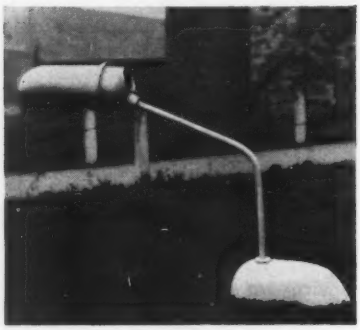
Measurement of the radiation level in the neighbourhood of nuclear installations, using sensitive detectors capable of measuring down to natural levels, serves as a continuous check on the methods used for controlling the spread of radioactivity. Elliott Bros. have recently developed a ground contamination monitor for this purpose. Originally developed for AERE, Harwell, the monitor is now available for general sale. Designed for outdoor service, the instrument makes use of two halogen quenched G-M counter tubes, which are mounted in close proximity under a light alloy cowling to provide protection against rain.

One tube is screened from beta activity but detects gamma activity from all directions, the weather shield offering virtually no screening to this. The second tube responds to beta activity in addition, although, because of the screening effect of the weather shield, it covers ground radiation only.

Separate 5-figure drum counters indicate the total counts due to gamma only and gamma plus ground beta. For the latter, count rate also is recorded continuously on a 7-day circular chart, scaled logarithmically from 3 to 300 counts per second and employing Teledeltos electrosensitive paper. An auxiliary marking on the periphery of the chart indicates the total count, giving a permanent record in addition to the drum counter indication.

*(Elliott Bros. (London), Ltd., Century Works, Lewisham, London, S.E.13.)*

**1181**



Ground contamination monitor developed for AERE, Harwell, by Elliott Bros. (London).

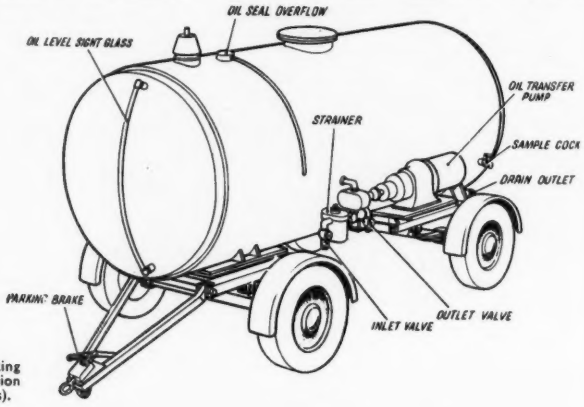
## Insulating-oil Transporters

Stream-Line Filters have supplemented their range of insulating-oil filters by the addition of mobile tanks for transporting oil on site. A pair of these tanks, together with a 250 g.p.h. insulating-oil purifier has been ordered for Berkeley power station by British Thomson-Houston. Although of similar construction, one tank is for clean oil and the other for dirty oil. Each has a capacity of 1,000 gallons, but larger capacities are available. This method of oil handling enables dirty oil to be pumped from a circuit breaker into the dirty tank and taken away for batch filtration at the customer's convenience.

The body of the unit is welded to channel bogie frames carried on spring axle assemblies with four pneumatic-tyred wheels. The towing bar incorporates an automatic overrun four-wheel braking gear. In addition to a drain outlet valve, sampling cock, oil-sealed overflow and oil-level sight glass, there is an oil-transfer pump-set. Inlet and outlet valves control the flow of oil and the power for the electric motor is obtained from suitable points on site.

*(Stream-Line Filters, Ltd., Henley Park, Guildford, Surrey.)*

**1182**




Mobile tank for transporting insulating oil at power station sites (Stream-Line Filters).

## High Efficiency Scintillation Counter

The SC/LP scintillation counter marketed by Panax Equipment, is intended for counting millimicrocurie quantities of very low-

Inserting a liquid sample for counting in the lead castle of the SC/LP scintillation counter made by Panax Equipment.

energy beta-radiation emitters such as tritium and carbon-14. Primarily for use with liquid phosphors it can also be converted to accommodate plastic phosphors and sodium iodide crystals. The equipment consists of a 1½ in-thick lead castle with a light-tight door interlocked with an EHT switch and a shutter assembly to protect the photo-multiplier.

For counting purposes, the unit is used in conjunction with a linear amplifier and suitable scaling apparatus incorporating discriminator and EHT supplies. Efficiencies of 10% for tritium and 50% for carbon-14 have been obtained at room temperature, but higher counting efficiencies can be achieved by cooling the castle in a standard refrigerator.

*(Panax Equipment, Ltd., Holmethorpe Industrial Estate, Redhill, Surrey.)*

**1183**

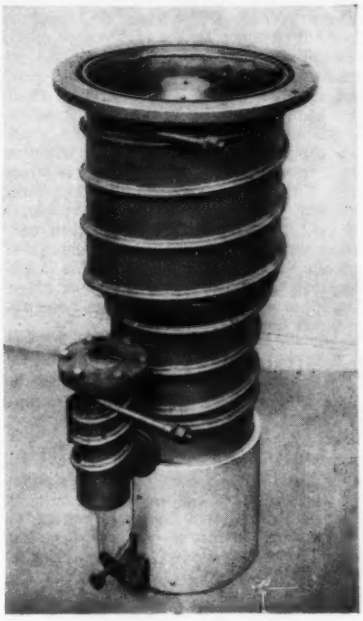
## Oil Diffusion Pump

The F1203 fractionating oil diffusion pump by Edwards High Vacuum, is one of the latest additions to the Speedivac range, filling the gap between the 9 in. and 16 in. models. These fractionating diffusion pumps are now available in a complete series of sizes from 2 in. to 24 in. bore, with speeds between 80 and 12,000 litres per second.

Like all Speedivac diffusion pumps, the F1203 has several unique features. Low backstreaming rates are achieved by integral splash baffles inside the pump, designed to prevent the top jet from running wet, a prime cause of vapour backstreaming into the vacuum system. An Edwards guard ring fitted over the top jet further reduces backstreaming to the exceptionally low figure of 0.005mm Hg/cm²min. To provide the high backing pressures, a side booster stage is incorporated. This also acts as a purifying jet, because selective cooling of the mixing tube in this side stage helps to ensure that only low vapour pressure oil is returned to the boiler, the high vapour pressure fractions present in the operating fluid tending to be stripped and ejected into the backing line.

The ultimate vacuum obtainable with the F1203 with cooling water at a temperature of 15°C, is well below $5 \times 10^{-7}$mm Hg using Apiezon oil C. The ultimate vacuum in the system can be further improved by using a refrigerated chevron baffle. Unbaffled, the speed of the pump at a vacuum of 3 by $10^{-4}$mm Hg is 2,700 litres per second for air and over 3,000 litres per second for hydrogen. With a heater loading of 2.25 kW the limiting backing pressure is 0.35 mm Hg using Apiezon oil C (with silicon 703 fluid the backing pressure is 0.5 mm Hg). For general duties the recommended rotary vacuum pump is the Speedivac 1SC450B single stage model, displacing 15 c.f.m.

The F1203 is an extremely compact pump being only 30 in. high. it is especially suitable for nuclear high vacuum systems. For this particular application it can be supplied complete with chevron baffle, either water cooled or equipped with a hermetically sealed refrigerator unit. A 12 in. hydraulically operated gate valve can also be fitted,



Speedivac F1203 fractionating oil diffusion pump manufactured by Edwards High Vacuum.

the whole equipment being housed in an angular steel frame, thus forming a compact self-contained unit, ideal for large automatic vacuum systems.

*(Edwards High Vacuum Ltd., Manor Royal, Crawley, Sussex.)*

**1184**

## Helium Leak Detector

Helium is used as the leak detection medium in the Helitest separately magnetized spectrometer now being marketed by Appleby and Ireland. The detector unit is capable of tracing one part helium in five million parts air.

To detect leaks in a closed system, the vessel is evacuated down to 1/10 mm Hg and a fine spray of helium is passed over the outside of the vessel. When the gas comes near an aperture, it is drawn into the system and then carried through to the detector, which immediately announces the presence of the helium. Using the vacuum method, it is possible to test leaks as low as $10^{-10}$ atmos. per cc per sec., i.e., less than $10^{-7}$ lusec. Another method is to pressurize the system under test with a gas containing helium; the suspected surfaces are then probed with an aspirating nozzle connected to the detector.

The Helitest is manufactured in two models; one automatic, the other manually operated. Accessories include a vapour and condensate trap cooled by liquid nitrogen, which is mounted at the inlet to the unit, a degasification chamber (supplied with the automatic set) and a standard test leak.

*(Appleby and Ireland Ltd., Basingstoke, Hants.)*

**1185**

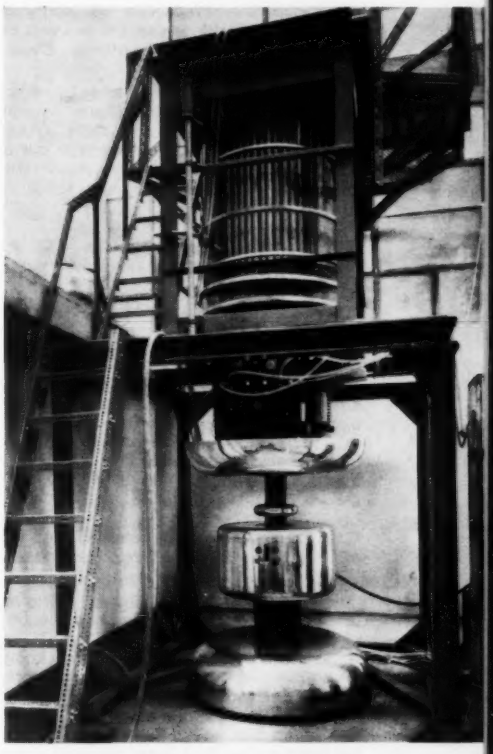
## Sub-critical Assembly

A light water moderated sub-critical assembly is being marketed in the U.K. by Miles Hivolt. The assembly, which was shown at Geneva last year, is manufactured by SAMES of Grenoble.

Intended for research applications, the equipment comprises a pulsed neutron generator, and a natural uranium assembly moderated by ordinary water. The neutron source is an accelerator with an output of $10^9$ neutron/sec, the ion beam current being 1 mA. The duration of the pulse can be varied according to the customer's requirements. A brief specification of the assembly indicates that the weight of uranium is 1620 kg; the reflector is 20 cm of water, pitch of core 45 cm, core diameter 60 cm and length of core 100 cm. The fuel comprises 162 uranium rods each comprising 10 slugs 10 cm long and 25 cm diameter. The elements are canned in aluminium.

*(Miles Hivolt Ltd., 91-93 Princedale Road, London, W.11.)*

**1186**



The Uranie sub-critical assembly is natural uranium fuelled and water moderated. The neutron source is an accelerator.

# Patents Reviewed

*These abstracts have been made from British Patent Specifications, complete copies of which can be obtained from the Patent Office, 25 Southampton Street, London, W.C.2, at 3s. 6d. each (including postage).*

**B.P. 798,518. Production of uranium.** To: U.K. Atomic Energy Authority.

It has been found that uranium tetrafluoride is particularly suitable for producing massive uranium metal and it may be obtained by reacting the tetrafluoride, which should have a particle size such that 75% pass a 60 mesh screen, with magnesium of a particle size not greater than 7 mesh.

**B.P. 798,644. Purification of carbon or graphite articles.** A. W. Beeston. To: Union Carbide Corp.

Impurities (boron, magnesium, calcium) are removed by subjecting carbon or graphite at elevated temperature (2,200 to 2,600°C) to a gaseous or vaporous fluorinating agent (fluorine, hydrogen fluoride or a halogenated hydrocarbon which forms fluorine at this temperature). Fluorine-derivatives of the impurities are removed as vapour or gas.

**B.P. 798,685. Separation of plutonium.** To: U.K. Atomic Energy Authority (U.S.A.).

Extraction of plutonium from irradiated uranium dissolved in nitric acid, in which the plutonium is present in extremely low concentration, is effected by precipitating the plutonium as a phosphate with bismuth phosphate as carrier.

**B.P. 798,687. Production of alloys of aluminium with plutonium, uranium or thorium.** To: U.K. Atomic Energy Authority (Canada).

A halide salt (fluoride) of plutonium, uranium or thorium mixed with excess aluminium is heated above the melting point of aluminium, in vacuo. The halide salt is reduced to the metal which alloys with aluminium while the aluminium halide is removed by distillation.

**B.P. 798,902. Measuring device.** G. F. Haliday, S. Jefferson. To: Bristol Aero-Engines, Ltd.

A radioactive source emitting beta rays, a detector responsive to the intensity of the beta rays set at a fixed distance from the source and means for masking the detector from the source. The mask is arranged in such a manner that the relative displacement between two components, e.g., two parts on a shaft changes the beam intensity and allows measurement of the torque or torsional strain as the twist in the shaft increases or is reduced.

**B.P. 799,001. Nuclear reactors.** A. W. Aikin. To: Metropolitan-Vickers Electrical Co., Ltd.

The reactor may be a fission or fusion reactor, e.g., a fast fission reactor, control of which is effected by varying the volume of a neutron absorbent liquid circulating through a ducting extending for an appreciable distance within the core of the reactor. The ducting is formed from two concentric flow and return pipes so that the neutron absorbent liquid (lithium) enters the core along one pipe and emerges along the other pipe. The liquid may be pumped upwards through the (smaller) flow pipe and spill over into the (larger) return pipe where the liquid level may be controlled (e.g. by controlling the flow from the outlet).

**B.P. 799,140. Electronic valve amplifier.** L. B. Mullett. To: U.K. Atomic Energy Authority.

The amplifier is based on the multipactor effect, a phenomenon experienced with surfaces whose secondary emission coefficient can be greater than one. A multipactor oscillator is described in U.S.P. 2,674,694. The structure includes two parallel plates to support an RF electric field and to generate electrons by the multipactor effect. One of the plates is perforated and an anode placed beyond the perforated plate collects those bunches of electrons which pass through the perforations. RF power is fed into the space between the plates and extracted from the electron interaction space between the cathode and anode structures. In a double coaxial line the inner line may provide the multipactor space, a perforated outer conductor may then constitute the inner conductor of the outer line wherein interaction takes place. The amplifier may alternatively be a double ridge-loaded waveguide. The spaces may be resonant cavities.

**B.P. 799,151. Measuring apparatus for ionizing radiations.** To: Assoc. des Ouvriers en Instruments de Précision (A.O.I.P.) (France).

A resistance of high value and an electrometer are connected in series to a charged condenser. The two electrodes connected across the terminals of the electrometer are arranged in a closed chamber forming an ionization chamber. One of the electrodes is connected to the wall of the chamber while the other electrode is insulated. For measuring low-intensity fields, a Geiger-Muller counter may be used and the two electrodes of this counter then connected to the electrodes of the electrometer.

**B.P. 799,212. Nuclear reactor.** P. Fortescue, J. P. Middleton. To: U.K. Atomic Energy Authority.

A stream of gas circulates in the primary circuit through the reactor core and is used to drive a gas turbine; it then passes through a heat exchanger, and a compressor to be compressed back to a sufficient pressure to circulate the coolant. The secondary circuit from the heat exchanger provides heat for power production by any suitable means.

**B.P. 799,546. Electromagnetic pumps.** D. A. Watt. To: U.K. Atomic Energy Authority.

Refers to a static return conductor arrangement to obtain complete compensation for the end effects ("armature reaction"). The return conductor is profiled to correspond to the significant limit of the current flow in the fluid duct when viewed in the direction of the magnetic field. Its thickness is varied so that the current distribution is similar to that in the liquid being pumped and in the duct.

**B.P. 799,575. Nuclear power plant.** P. Fortescue. To: U.K. Atomic Energy Authority.

A plant for experimental or breeding purposes is built up of a reaction vessel containing a critical mass of fissile material (enriched uranium hexafluoride and beryllium fluoride as moderator in a nickel vessel), a temperature and pressure reducing device (turbine), a heat exchanger and a condenser. The fissile gas is expanded in the reaction vessel, reduced in temperature and pressure in the turbine, used as heating medium in the exchanger and returned to the condenser.

**B.P. 799,641. Spark recorders.** J. Pickup. To: U.K. Atomic Energy Authority.

A spark between an indicating needle (e.g., of a microammeter) and a contact element may not only be required to record on paper the position of the needle at any time but also to operate automatically a visible or audible alarm or a controlling mechanism when the meter needle assumes a predetermined position. One solution of the problem is described in B.P. 708,110. A simpler arrangement is obtained with a contact element divided into two segments to provide alternative paths for the spark discharge current and varying the effective position of the division.

**B.P. 799,662. Production of plutonium-aluminium alloys.** To: U.K. Atomic Energy Authority (Canada).

Plutonium oxide is mixed with cryolite and the mixture added to molten aluminium. The mass is maintained at 1050 to 1100°C to reduce the plutonium oxide and to alloy the plutonium and the aluminium.

**B.P. 799,725. Nuclear reactor and method of operating same.** To: Babcock and Wilcox Co. (U.S.A.).

The thermal reactor has fissile fuel elements in a core chamber and fertile material elements in a closed blanket chamber arranged longitudinally around the core chamber. Steam is generated from the heat released in the core and superheated by the heat released in the fertile material of the blanket chamber. The fertile material and the fuel elements are interchangeably positioned and this position programmed to have a constant ratio between the heat absorbed in the blanket and that given up in the core.

**B.P. 799,771. Method for enclosing a uranium body in a metallic sheath.** To: U.K. Atomic Energy Authority.

A mass of metal powder (beryllium, zirconium, tantalum, niobium, iron, copper, brass, bronze or alloys of aluminium or beryllium) is compacted about a core of uranium metal, powder and core being above the beta-gamma transition point of uranium.

**B.P. 800,388. Nuclear reactors.** M. L. A. Moncrieff. To: General Electric Co., Ltd.

The reactor core is arranged within a pressure vessel of concrete consisting of a central annular section and two end closure sections. The joints between the sections are constructed as dry joints during the fabrication of the vessel. The sections are coupled by mild steel bars having anchoring plates in the adjacent sections between longitudinal prestressing bars. By this means relative lateral movement is possible between adjacent sections while the coupled parts remain resistant to internal pressure.

"NUCLEAR ENGINEERING"

1959

# BUYERS' GUIDE

to

## British manufacturers

and

## suppliers

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Reinforced concrete construction, piling.
WOODMAN AND SON (BUILDERS), LTD.
Contractors.
WRIGHT ANDERSON AND CO., LTD.

## 118 BURST FUEL ELEMENT DETECTION

DOWTY NUCLEONICS, LTD.
Complete plant.
FAIREY AVIATION CO., LTD., THE.
HALL, MATTHEW, AND CO., LTD.
Installation.
LUCAS, JOSEPH, LTD.
Valves.
MARSTON EXCELSIOR, LTD.
Tube bundles, s.s.
PLESSEY NUCLEONICS, LTD.
Complete plant.
POWER AUXILIARIES, LTD.
Hoses.
TALBOT STEAD TUBE CO., LTD.
S.s. tubes.
TUBE PRODUCTS, LTD.
S.s. snifter tubes.

## 119 BUSHES

HALL AND KAY, LTD.
Brass, steel rivet.
PERMALI, LTD.
H.V., S.R.B.P.
RANSOME AND MARLES BEARING CO., LTD.
Linear ball.
SPE CO., LTD.
"Walter" type split, plain, specials.
UNITED COKE AND CHEMICALS CO., LTD.
"Orkot" fabric reinforced resin; bearings.

## C

## 120 CABINETS; Panels
*see also ENGRAVING*

A.C.M. ELECTRONICS.
Chassis, racks.
AUSTIN TAYLOR ELECTRICAL, LTD.
BROWN, E. G., AND CO., LTD.
Consoles.
DEWHURST AND PARTNER, LTD.
Panels, desks, units.
DYNATRON RADIO, LTD.
Instrument cases, racks.
DUTHIE, R. HUTCHEON, AND SON, LTD.
ETHER, LTD.
FIELD AND GRANT, LTD.
Mimic diagrams; distribution boards, switchboards.
HASSETT AND HARPER, LTD.
Sheet metal.
IMHOF, ALFRED, LTD.
Instrument cases, consoles, cubicles.
KENT, GEORGE, LTD.
KILPATRICK, JAMES, AND SON, LTD.
LUND BROS. AND CO., LTD.
Control consoles, desks, cases, chassis, racks.
LYONS, CLAUDE, LTD.
MALONE INSTRUMENT CO., LTD., THE.
MARSH, H. S., LTD.
MILLETT, LEVENS (INSTRUMENTS AND ENGINEERING), LTD.
MOORES (BOURNEMOUTH), LTD.
NEW WESTERN (ENGINEERING), LTD.
"Lockmet," "Lockplast" panels, cubicles.
ODDIE FASTENERS.
Panel fasteners.
PHILLIPS AND BONSON, LTD.
Cases, chassis, handles, assembly.
RITHERDON AND CO., LTD.
Cubicles.

## 120 CABINETS; Panels (contd.)

**RUBERY, OWEN AND CO., LTD.**
**SILENTBLOC, LTD.**
Anti-vibration mountings, panel fasteners.
**SOUTH WALES SWITCHGEAR, LTD.**
Control boards, desks.
**THORN ELECTRICAL INDUSTRIES, LTD**
"Plasteck" trans-illuminated fascias.
**UNIVERSAL PATTERN AND PRECISION ENG. CO., LTD., THE.**
Glass cloth.
**WILFLO PRODUCTS, LTD.**

## 121 CABLES, ELECTRIC; Accessories

**ACCLES AND SHELVOKE, LTD.**
Accessories, "Acvoke," spiking guns.
**AERIALITE, LTD.**
Plastics, rubber insulated; power, multi-core.
**BOWTHORPE ELECTRIC CO., LTD.**
Accessories; overhead light fittings.
**BRITISH DRIVER-HARRIS CO., LTD.**
**BRITISH INSULATED CALLENDER'S CABLES, LTD.**
Variety; cabled copper tube; wire.
**CROMPTON PARKINSON, LTD.**
Paper, rubber, thermoplastic insulated.
**DAY, J., AND CO. (DERBY WORKS), LTD.**
PVC; wires.
**DURATUBE AND WIRE, LTD.**
Wires, thermoplastic insulated.
**ERMA, LTD.**
Accessories, terminals, lugs, crimping, strippers.
**E.R.S. (LONDON), LTD.**
Connectors all types, looms, test to 10kV.
**GEIPEL, WILLIAM, LTD.**
Rubber, thermoplastic insulated; multicore.
**GENERAL CABLE MANUFACTURING CO., LTD., THE.**
Rubber, plastic, paper, silicone-rubber covered.
**GIRDLESTONE PUMPS, LTD.**
Co-axial connectors.
**HELLERMAN, LTD.**
Binding, marking systems, cable entries.
**JOHNSON AND PHILLIPS, LTD.**
**LIVERPOOL ELECTRIC CABLE CO., LTD.**
Rubber, plastics insulated.
**MERSEY CABLE WORKS, LTD.**
Rubber, thermoplastic, varnished, irradiated polythene.
**PERMANOID, LTD.**
Plastics, high-temperature insulated.
**PYROTENAX, LTD.**
Pyrotenax mineral insulated.
**SAXONIA ELECTRICAL WIRE CO., LTD., THE.**
Thermo, instrument wires, sleevings.
**SIEMENS EDISON SWAN, LTD.**
Heavy-duty.
**ST. HELENS CABLE AND RUBBER CO., LTD.**
Rubber, thermoplastic insulated.
**TELEGRAPH CONSTRUCTION AND MAINTENANCE, THE.**
Range; wires; accessories.
**WANDLESIDE CABLE WORKS, LTD.**
PTFE, PTFE/glass insulated.
**WARD AND GOLDSTONE, LTD.**
Accessories.
**YORKSHIRE IMPERIAL METALS, LTD.**
Cable sockets.

## 122 CARBON DIOXIDE

**DISTILLERS CO., LTD., THE.**
**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
Liquid; bulk; "Drikold" solid; liquefiers.
**POWER-GAS CORPORATION, LTD., THE.**

## 123 CARBON DIOXIDE PLANT

**BIRLEC, LTD.**
Dryers.
**DISTILLERS CO., LTD., THE.**
Storage, evaporation, handling; bursting discs.
**FLIGHT REFUELLING, LTD.**
Purging trolleys, self-sealing couplings; hose.
**HOLMES, W. C., AND CO., LTD.**
Storage, vaporizing plant.
**LLOYD AND ROSS, LTD.**
Liquid, storage, production, plant.
**YORK SHIPLEY, LTD.**
Compressors.

## 124 CASTINGS

**ALLEN, EDGAR, AND CO., LTD.**
Carbon, alloy, highly alloyed steels.
**ANTI-ATTRITION METAL CO., LTD., THE.**
Non-ferrous, chill, spun, gravity die, shell moulding.
**ASHMORE, BENSON, PEASE AND CO.**
High-duty, meehanite iron.
**ATLAS STEEL FOUNDRY AND ENGINEERING CO., LTD., THE.**
Steel.
**BARNSLEY, JOHN, AND SONS, LTD.**
Grey; malleable iron; steel; non-ferrous.
**BENNIS COMBUSTION, LTD.**
Grey, alloy, high-duty iron.
**BEARDMORE, WILLIAM, AND CO., LTD.**
**BIRFIELD INDUSTRIES, LTD.**
Aluminium, magnesium alloy, s.s.; automatic.
**BIRKETT, T. M., BILLINGTON AND NEWTON, LTD.**
Non-ferrous; high-duty iron.
**BIRMINGHAM ALUMINIUM CASTING (1903) CO., LTD.**
Aluminium, magnesium alloys.
**BROWN, DAVID, CORPORATION (SALES), LTD., THE.**
Alloy, carbon, heat-resisting steel; centrifugal s.s., bronze.
**BROWN, DAVID, INDUSTRIES, LTD.**
S.s., alloy, carbon steel.
**BROWN, JOHN, AND CO., LTD.**
Iron.
**BUTTERLEY CO., LTD., THE.**
Meehanite iron to 20 tons.
**CAMERON AND ROBERTSON, LTD.**
Meehanite, to 1 ton; patterns.
**CONSTRUCTIONAL ENGINEERING CO., LTD., THE.**
Foundry plant.
**CRAVEN BROTHERS (MANCHESTER), LTD.**
To 40 tons; non-ferrous.
**COCKBURN'S, LTD.**
Non-ferrous to 15 cwt.
**CROFTS (ENGINEERS), LTD.**
Iron, steel, non-ferrous.
**DARWINS, LTD.**
Heat, corrosion resisting, alloys; s.s.
**DAVISON AND CO. (HEXHAM), LTD.**
**DIALOY, LTD.**
Diecastings; aluminium alloys, brass, alum-bronze.
**ENGLISH STEEL CASTINGS CORPORATION, LTD.**
Steel.
**FIRTH-VICKERS STAINLESS STEELS, LTD.**
Alloy, s.s.; precision, static, centrispun, shell moulded.
**FOLLSAIN-WYCLIFFE FOUNDRIES, LTD.**
Blackheart M.I.; heat resisting steel; alloy; iron.
**FROST, H., AND CO., LTD.**
Diecastings, zinc alloy.
**GARDNER, J. STARKIE, LTD.**
Non-ferrous.
**GRANGE-CAMELON IRON CO., LTD.**
**GRAZEBROOK, M. AND W., LTD.**
Heavy; iron.
**GUEST INDUSTRIALS, LTD.**
Steel; Agents for S.I.A.C.
**HADFIELDS, LTD.**
Steel.
**HARLAND AND WOLFF, LTD.**
Ferrous, 100 tons; s.g. iron, non-ferrous.
**HEPWORTH AND GRANDAGE, LTD.**
S.g. iron.
**INTERNATIONAL MEEHANITE METAL CO., LTD., THE.**
Meehanite iron.
**JACKMAN, J. W., AND CO., LTD.**
Foundry plant, equipment.
**JESSOP, WM., AND SONS, LTD.**
Constructional; steel, s.s.
**K. AND L. STEELFOUNDERS AND ENGINEERS, LTD.**
Carbon, low, high alloy, manganese, steel; treated.
**LAKE AND ELLIOT, LTD.**
Carbon, chrome, molybdenum, stainless, steels.
**LANGLEY ALLOYS, LTD.**
Stainless steel, nickel alloy.
**LLOYD, F. H., AND CO., LTD.**
Carbon, alloy steel, s.g. to 25 tons; unmachined, machined.
**LONDON METAL WAREHOUSES, LTD.**
Non-ferrous.
**LOW, ARCHIBALD, AND SONS, LTD.**
Non-ferrous.
**METROPOLITAN PLASTICS, LTD.**
Zinc, alloy, pressure die.
**MILLS PAUGH, LTD.**
Centrifugal, ferrous, non-ferrous to 60 in. dia., 30 ft length.
**OSBORN, SAMUEL, AND CO., LTD.**
Steel.
**OXLEY, WM., AND CO., LTD.**
Stainless steel.
**PHOSPHOR BRONZE CO., LTD., THE.**
Non-ferrous, monel, stainless, alloyed steel; finished.
**RHODES, B., AND SON, LTD.**
Pure nickel, monel, nickel alloy; machined.
**RYDER, THOS., AND CO. (MANCHESTER), LTD.**
G.M. phos. mang. bronze, C.I., pure aluminium.
**SALTER, GEO., AND CO., LTD.**
Grey iron.
**SANDFORD, THOMAS, (ROCHDALE), LTD.**
Non-ferrous.
**SAVILLE, J. J., AND CO., LTD.**
**SHEEPBRIDGE ALLOY CASTINGS, LTD.**
Special shell moulding.
**SHEEPBRIDGE EQUIPMENT, LTD.**
Iron, alloy, s.g. iron to 10 tons; steel to 35 cwt.
**SLOUGH METALS, LTD.**
Aluminium alloy, bonze, lead.
**SMITH, W. H., AND CO. (WHITCHURCH), LTD.**
Grey iron to 10 cwt.
**STANTON IRONWORKS CO., LTD., THE.**
General; special.
**STEEL CO. OF SCOTLAND, LTD., THE.**
Steel.
**STERLING METALS, LTD.**
Aluminium, magnesium, alloy.
**STEWARTS AND LLOYDS, LTD.**
Steel.
**SUTCLIFFE, SPEAKMAN AND CO., LTD.**
Heat resisting.
**TERRASPAN, LTD.**
Stainless steel.
**WALKER, C. AND W., LTD.**
Ferrous.
**WILLAN, G. L., LTD.**
**WILSON PIPE FITTINGS, LTD.**
Aluminium, pressure, die, gravity, sand, (A).

## 125 CEMENT

**ACALOR (1948), LTD.**
Resistant floors, tank linings.
**ANCORITE, LTD.**
Chemical resisting; linings.
**CHEMICAL BUILDING PRODUCTS, LTD.**
Additives.
**CURTIS, A. L., (OMX), LTD.**
Fire-proof.
**DICKENS, STUART B., LTD.**
Concrete curing; compounds; accelerators.
**ESKETT LIMESTONE QUARRIES, LTD., THE.**
Aggregate.
**EVODE, LTD.**
Hardeners, sealers, waterproofing.
**HAWORTH, F., (A.R.C.), LTD.**
Acid, alkali resisting.
**LAFARGE ALUMINOUS CEMENT CO., LTD.**
"Ciment Fondu" high alumina; "secar 250" calcium aluminate.
**PORTASILO, LTD.**
Storage, silos, pressurized containers.
**PRODORITE, LTD.**
Corrosion resisting.
**WELFORD GRAVELS, LTD.**
Aggregates.

## 126 CENTRIFUGES

**ALFA-LAVAL CO., LTD.**
Oil purification.
**BROADBENT, THOMAS, AND SONS, LTD.**
Laboratory, separating, clarifying, drying.
**SHARPLES CENTRIFUGES, LTD.**

## 127 CERAMICS

**AEROX, LTD.**
For filtration, diffusion, aeration, electrolysis, fluidization.
**AUTOFLOW ENGINEERING, LTD.**
Grinding, cutting, machining.
**BAYLEY, F. S., CLANAHAN AND CO., LTD.**
Sintered alumina, zirconia, magnesia, spinel.
**BOULTON, WILLIAM, LTD.**
Machinery.
**DOULTON INDUSTRIAL PORCELAINS, LTD.**
Piping, cocks, pumps, vessels.
**HATHERNWARE, LTD.**
Chemical stoneware, porcelain.
**LANGLEY LONDON, LTD.**
Tiles for cooling ponds, turbine halls. (A)
**LODGE PLUGS, LTD.**
Alumina, "Sintox" ceramics.
**MORGAN REFRACTORIES, LTD.**
Structural refractories; furnace tubes; pyrometer sheaths; oxide ware.
**NORTON GRINDING WHEEL CO., LTD.**
Porous media.
**PLESSEY CO., LTD., THE.**
Alumina, ferrites.
**ROYAL WORCESTER INDUSTRIAL, LTD., THE.**
Aluminium oxide tubes, rods, formers.
**TAYLOR, TUNNICLIFF AND CO., LTD.**
**TELEGRAPH CONDENSER CO., LTD., THE.**
**UNITED INSULATOR DIVISION.**
Whole field.

## 128 CHAINS

FERRY CHAIN CO., LTD.
RENOLD CHAINS, LTD.
Chains; accessories.

## 129 CHARGE/DISCHARGE GEAR

ARMSTRONG SIDDELEY MOTORS, LTD.
Recirculating ball lead screws.
BRISTOL AERO-ENGINES, LTD.
BROWN, JOHN, AND CO., LTD.
Machines and ancillaries.
DOWTY NUCLEONICS, LTD.
Standpipe closures.
ENGLISH ELECTRIC CO., LTD., THE.
Complete equipment.
FAIREY AVIATION CO., LTD., THE.
Refuelling machines, shield plugs.
FLIGHT REFUELLING, LTD.
Standpipe self-aligning, self-locking seal plugs.
GEARTIGHT UNIONS, LTD.
Closure units for standpipes.
HALL ENGINEERING, LTD.
Charge tubes, irradiation flux scanner tubes.
HALL, MATTHEW, AND CO., LTD.
Tube cooling assemblies.
METRO-FLEX ATOMIC ENGINEERING, LTD.
Gas-tight sealing.
NAPIER, D., AND SON, LTD.
NEWBURGH ENGINEERING CO., LTD.
Components.
POWER AUXILIARIES, LTD.
Hoses.
RICHARDS AND ROSS, LTD.
Standpipes, charge tubes.
STRACHAN AND HENSHAW, LTD.
T.I. NUCLEAR ENGINEERING, LTD.
Charge tubes, shield plugs.
UNIT SUPERHEATER AND PIPE CO., LTD., THE.
Reactor standpipes.
VICKERS-ARMSTRONGS (ENGINEERS), LTD.
VICKERS NUCLEAR ENGINEERING, LTD.

## 130 CHEMICALS; Gases

BRITISH DRUG HOUSES, LTD., THE.
Specially purified.
BRITISH OXYGEN GASES, LTD.
CHAPMAN, SPENCER, AND MESSEL, LTD.
Acids.
GURR, EDWARD, LTD.
Biological stains.
HOLMES, W. C., AND CO., LTD.
Gas generators.
HOPKIN AND WILLIAMS, LTD.
For research analysis.
IMPERIAL CHEMICAL INDUSTRIES, LTD.
INTERNATIONAL ELECTROLYTIC PLANT CO., LTD., THE.
Electrolytic hydrogen/oxygen plant.
LUNEVALE PRODUCTS, LTD.
Organo-mercurial compounds.
NASH AND THOMPSON, LTD.
Scintillation purity.
PAGE, CHAS., AND CO., LTD.
Agent.
POWER-GAS CORPORATION, LTD., THE.
Inert gases, hydrogen.
SATURN INDUSTRIAL GASES, LTD.
Industrial gases.
THOMPSON AND CAPPER, LTD.
Tableting, pelleting service.

## 131 CIVIL ENGINEERING

*see also BUILDING*

BALFOUR BEATTY AND CO., LTD.
BRAND, CHARLES, AND SON, LTD.
CEMENTATION CO., LTD.
CHIVERS, W. E., AND SONS, LTD.
COSTAIN, RICHARD, LTD.
COWLEY, MARTIN, LTD.
DEMOLITION AND CONSTRUCTION CO., LTD., THE.
DURHAM, GORDON, AND CO., LTD.
FOWLER, JOHN, AND CO. (LEEDS), LTD.
Crawler tractor ancillaries.
FITZPATRICK AND SON (CONTRACTORS), LTD.
FLATHER, J. W., LTD.
Public works contractors.
FORD AND WALTON, LTD.
GAYLORD, EDWARDS AND CO., LTD.
Plant hire.
GRANT, LYON AND CO., LTD.
HARBOUR AND GENERAL WORKS, LTD.
HOLLOWAY BROS. (LONDON), LTD.
LAING, JOHN, AND SON, LTD.
McALPINE, SIR ROBERT AND SONS, LTD.
MACKAY INDUSTRIAL EQUIPMENT, LTD.
Equipment (A).
MACKLEY, J. T., AND CO., LTD.
MARSHALL, SONS AND CO., LTD.
Crawlers.
M.B. DREDGING CO., LTD.
Dredging; reclamation.
MEARS BROS. (CONTRACTORS), LTD.
MITCHELL CONSTRUCTION CO., LTD., THE.
MOTOR RAIL, LTD.
Diesel dumpers, locomotives.
MOWLEM, JOHN, AND CO., LTD.
NUCLEAR CIVIL CONSTRUCTIONS, LTD.
ROTINOFF GROUP.
SIMON-CARVES, LTD.
Biological shielding, shield cooling systems.
STEEL FABRICATORS (CARDIFF), LTD.
Dumpers, hydraulic loaders, excavators.
STEPHENSON, G., (BUILDERS AND CONTRACTORS), LTD.
STEWART, THOMAS C., (CONTRACTORS), LTD.
STIRLING, J. A., LTD.
TAYLOR WOODROW CONSTRUCTION, LTD.
TRENTHAM, G. PERCY, LTD.
TURRIFF CONSTRUCTION CORP., LTD.
WIMPENNY, J., AND CO., LTD.

## 132 CLEANING; Descaling

AIRNESCO PRODUCTS, LTD.
Boiler, heat exchanger, tools.
BASTIAN AND ALLEN, LTD.
Speedyjet steam cleaners.
BIVAC AIR CO., LTD.
Portable industrial vacuum cleaners.
CLENSOL, LTD.
Descaling, derusting, degreasing, chemicals.
C.P. EQUIPMENT, LTD.
C.P. sellers hydraulic high pressure jet.
DAWE INSTRUMENTS, LTD.
Ultrasonic.
DENDIX BRUSHES, LTD.
Rotary maintenance brushes.
FOX CHEMICAL-ENGINEERING WORKS, LTD.
Degreasing.
GEM POWER BRUSHES, LTD.
Rotary; hand, industrial wire brushes.
GENERAL DESCALING CO., LTD.
Equipment, service; pipeline, duct, sewer.
H.N. ELECTRICAL SUPPLIES, LTD.
"Crustex" ultrasonic descaling.
HOPKINS, G., AND SONS, LTD.
General purpose ultrasonic washing machines.
HOUSEMAN AND THOMPSON, LTD.
Descaling, degreasing, pre-commissioning.
IMPERIAL CHEMICAL INDUSTRIES, LTD.
Alkaline degreasing agents, plants.
INDUSTRIAL DESCALING TOOLS, LTD.
Tubes, ¼ in. to 16 in. i.d.
KLEEN-E-ZE BRUSH CO., LTD., THE.
Bullets, guns, for condensers.
LAMSON ENGINEERING CO., LTD.
MORRIS, B. O., LTD.
Deburring machines, rotary cutters, brushes.
Central vacuum.
MULLARD EQUIPMENT, LTD.
Ultrasonic decontamination.
SERVICE ELECTRIC CO., LTD.
Industrial vacuum cleaners.
SPENCER AND HALSTEAD, LTD.
Airless, air blast equipment.
ULTRASONICS, LTD.
Ultrasonic.
VACU-BLAST, LTD.
Pipe, weld.

## 133 CLEAN ROOM

B.M.B. (SALES), LTD.
Sectional areas.
CRAVENS, LTD.
Facilities.
NEW WELBECK, LTD.
Protection machines.
UNIVERSAL PATTERN AND PRECISION ENG. CO., LTD., THE.
Facilities.

## 134 COLUMNS, CHEMICAL

ASHMORE, BENSON, PEASE AND CO.
Separation.
BROWN, JOHN, AND CO., LTD.
Chemical separation.
DAVEY, PAXMAN AND CO., LTD.
Chemical separation.
HEAT TRANSFER, LTD.
Chemical separation.
HYDRONYL SYNDICATE, LTD., THE.
Packings, tower, liquid-liquid, gas absorption.
KNITMESH, LTD.
Packings.
PEABODY, LTD.
Gas scrubbers.
THOMPSON BROS. (BILSTON), LTD.
Distillation, reflux, condensers.

## 135 COMPRESSORS

ADAMSON, DANIEL, AND CO., LTD.
AIR PUMPS, LTD.
Portable, stationary.
ALLEY AND MACLELLAN (POLMADIE), LTD.
Air, gas.
ASSOCIATED ELECTRICAL INDUSTRIES, LTD.
Centrifugal.
ATLAS COPCO (GREAT BRITAIN), LTD.
Air.
B.E.N. PATENTS, LTD.
Air.
DONKIN, BRYAN, CO., LTD., THE.
BRISTOL AERO-ENGINES, LTD.
Aerodynamic.
BROOM AND WADE, LTD.
Air; portable, stationary.
BROTHERHOOD, PETER, LTD.
Air, gas.
CENTRAX, LTD.
Turbine blades.
CONSOLIDATED PNEUMATIC TOOL CO., LTD.
Portable to 600 c.f.m.; stationary to 3,000 c.f.m.
C.T. (LONDON), LTD.
CUTT, J. AND K. K., LTD.
Air.
GOODWIN, ARNOLD, LTD.
Air.
GUYSON INDUSTRIAL EQUIPMENT, LTD.
Air.
HAMWORTHY ENGINEERING, LTD.
HARLAND AND WOLFF, LTD.
Gas.
HICK HARGREAVES AND CO., LTD.
Rotary.
HOLLAND, B. A., ENGINEERING CO., LTD., THE.
Rotary; air, gas.
HOLMAN BROS., LTD.
Air.
INGERSOLL-RAND CO., LTD.
Air.
LACY-HUBERT AND CO., LTD.
Air; reciprocating, non-lubricated rotary.
LIGHTFOOT REFRIGERATION CO., LTD., THE.
LUCAS, JOSEPH, LTD.
Portable.
MACKAY INDUSTRIAL EQUIPMENT, LTD.
"Mackay Dac. 130" free piston.
NAPIER, D., AND SON, LTD.
NORTHEY ROTARY COMPRESSORS, LTD.
Oil free.
REAVELL AND CO., LTD.
Oil free, air, gas.
RICHARDSONS, WESTGARTH AND CO., LTD.
Centrifugal, axial flow.
RICHARDSON, R. J., AND SONS, LTD.
(A).
SEAGERS, LTD.
High pressure, air, industrial gases.
STOVIS ENGINEERING CO., LTD.
Air, various.
SULZER BROS. (LONDON), LTD.
WILD, THOS. C., (MACHINERY), LTD.
Air. (A)
WILLIAMS AND JAMES (ENGINEERS), LTD.
Free air, high pressure to 6,000 p.s.i.
WILSON, ALEXANDER, (ABERDEEN), LTD.
Air.
YORK SHIPLEY, LTD.
Carbon dioxide.

## 136 COMPUTERS

AIR TRAINERS LINK, LTD.
D.C., mechanical, analogue components, power station simulators.
ARCHIMEDES-DIEHL MACHINE CO., LTD.
Automatic desk.
ARMSTRONG WHITWORTH, SIR W. G., AIRCRAFT, LTD.
Digit print-out equipment.
BRITISH OLIVETTI, LTD.
Calculating machines.
CARBIC, LTD.
Otis King calculators.
DECCA RADAR, LTD.
Components.
DOBBIE McINNES (ELECTRONICS), LTD.
Digital, analogue, converters, readers.

## 136 COMPUTERS (contd.)

**ELLIOTT NUCLEONICS, LTD.**
Analogue, digital; data handling equipment.
**ENGLISH ELECTRIC CO., LTD., The.**
Machines, facilities.
**ENGLISH NUMBERING MACHINES, LTD.**
Numbering machines, boxes, wheels, pinions.
**EVERSHED AND VIGNOLES, LTD.**
Analogue.
**FAIREY AVIATION CO., LTD., THE.**
Analogue; reactor simulators.
**HAWKER SIDDELEY NUCLEAR POWER CO., LTD.**
Design, construction.
**HONEYWELL CONTROLS, LTD.**
Reactor simulator (U.S.A. mft.).
**INTEGRA, LEEDS AND NORTHRUP, LTD.**
Reactor simulators.
**K.G.M. ELECTRONICS, LTD.**
Read-out units.
**LANGHAM THOMPSON, J., LTD.**
Digital indicating equipment.
**LINDARS AUTOMATION, LTD.**
Data logging, process control.
**LINTRONIC, LTD.**
Convertors.
**LUCAS, JOSEPH, LTD.**
Analogue; simulators.
**METROPOLITAN-VICKERS ELECTRICAL CO., LTD.**
Data handling equipment.
**NATIONAL CASH REGISTER CO., LTD.**
"National-Elliott 802" desk digital.
**RACAL ENGINEERING, LTD.**
Digital delay generators, counters, print-out, in-line read-out.
**ROBINSON AND PARTNERS, F. C., LTD.**
Analogue network analyser.
**SANDERS-ROE, LTD.**
Analogue.
**SHORT BROS. AND HARLAND, LTD.**
General-purpose analogue.
**SOLARTRON ELECTRONIC GROUP, LTD.**
Analogue, reactor simulation, transfer function analyser.
**SOUTHERN INSTRUMENTS, LTD.**
Data reduction handling equipment.
**SPERRY GYROSCOPE CO., LTD.**
Data transmission elements, magnetic storage devices.
**SUNVIC CONTROLS, LTD.**
Data-processing.
**THORN ELECTRICAL INDUSTRIES, LTD.**
Digital indicators.
**WHITE AND RICHES, LTD.**
Systems design.
**WINSTON ELECTRONICS, LTD.**
Analogue, data processing systems (A).

## 137 CONTROL GEAR

**ARDLEIGH ENGINEERING, LTD.**
Governors; systems.
**ARMSTRONG, SIR W. G., WHITWORTH AIRCRAFT, LTD.**
Remote, supervisory telemetry systems.
**ARROW ELECTRIC SWITCHES, LTD.**
Motor.
**ASSOCIATED ELECTRICAL INDUSTRIES, LTD.**
Large electric control schemes.
**AUTOMATIC TELEPHONE AND ELECTRIC CO., LTD.**
Supervisory telemetering equipment.
**AYLING NUCLEAR EQUIPMENT CO.**
**BIRFIELD INDUSTRIES, LTD.**
Automatic air, oil, water.
**BLACK AUTOMATIC CONTROLS, LTD.**
Special.
**BOWDEN (ENGINEERS), LTD.**
Cable assemblies.
**BRITISH THOMSON-HOUSTON CO., LTD., THE.**
Electronic; motor, cranes.
**BROOKHIRST SWITCHGEAR, LTD.**
Motor.
**CATTERSON-SMITH, R. M., LTD.**
Furnaces.
**C.A.V., LTD.**
Starters, control boards.
**CROSBY VALVE AND ENGINEERING CO., LTD.**
Valve positioners, pressure regulators; controllers.
**DEPENDABLE RELAY CO., LTD.**
**DRAYTON REGULATOR AND INSTRUMENT CO., LTD.**
Pneumatic actuators.
**ELECTRICAL POWER ENGINEERING CO. (B'HAM), LTD., THE.**
Flameproof.
**ELECTRO DYNAMIC CONSTRUCTION CO., LTD.**
Automatic.
**ELECTROFLO METERS CO., LTD.**
Boiler, process, supervisory.
**ELECTRO-HYDRAULICS, LTD.**
Hydraulic, pneumatic, actuators.
**E.M.B. CO., LTD.**
**FAIREY AVIATION CO. LTD., THE.**
Automatic.
**FISHER GOVERNOR CO., LTD.**
Regulators; systems.
**FRASER, ANDREW, AND CO., LTD.**
Hydraulic.
**GORDON, JAMES, AND CO., LTD.**
Automatic; boilers, turbines.
**GRAVINER MANUFACTURING CO., LTD.**
Temperature.
**GRANIC ELECTRIC CO., LTD.**
Pumps, compressors, cranes.
**LANCASHIRE DYNAMO NEVELIN, LTD.**
**LANG PNEUMATIC, LTD.**
Pneumatic.
**LAURENCE, SCOTT AND ELECTROMOTORS, LTD.**
Motor.
**LEE GUINNESS, LTD.**
Automatic; contactor type; motor.
**LUCAS, JOSEPH, LTD.**
Hydraulic, pneumatic.
**MANN, ALBERT, ENGINEERING CO., LTD.**
Remote systems.
**METROPOLITAN-VICKERS ELECTRICAL CO., LTD.**
**MILES DEVELOPMENT PRODUCTS, LTD.**
Remote control.
**NELSON, W. AND H., LTD.**
Automatic, manually operated, electrical.
**NUMATION VALVES, LTD.**
Electro-hydro-pneumatic actuators.
**P.A.M., LTD.**
"Tem-Con," temperature, humidity.
**RHEOSTATIC CO., LTD., THE.**
Automatic temperature equipment.
**RHYMNEY ENGINEERING CO., LTD.**
Electrical, hydraulic, pneumatic.
**SANDERS, W. H., (ELECTRONICS), LTD.**
Magnetic amplifier systems.
**SCREW MACHINE PRODUCTS, LTD.**
Components.
**SPERRY GYROSCOPE CO., LTD.**
Programme controllers.
**TELEFLEX PRODUCTS, LTD.**
Remote actuators; valves.
**WALKER, C. AND W., LTD.**
Remote.
**WESTERN MANUFACTURING (READING), LTD.**
Hydraulic, pneumatic, electronic.
**WESTOOL, LTD.**
**WHITEHEAD, JOHN, ENG. (WILLSD.), LTD.**
Electro mechanical specials.

## 138 CONTROL RODS

**ARMSTRONG SIDDELEY MOTORS, LTD.**
**BORAX AND CHEMICALS, LTD.**
**BRISTOL AERO-ENGINES, LTD.**
Mechanisms.
**BRITISH THOMSON-HOUSTON CO., LTD. THE.**
Actuator mechanisms control systems.
**BROWN, JOHN, AND CO., LTD.**
Mechanisms.
**ELECTRO-HYDRAULICS, LTD.**
Systems drives equipment.
**ELLAY TUBES, LTD.**
Tubes, sheaths.
**ELLIOTT NUCLEONICS, LTD.**
Actuating mechanisms.
**ENGLISH ELECTRIC CO., LTD., THE.**
**FAIREY AVIATION CO., LTD., THE.**
Flattening bars, control gear.
**FIRTH CLEVELAND INSTRUMENTS, LTD.**
Mechanisms.
**FLETCHER, C. W., AND SONS, LTD.**
Absorber plates.
**HADFIELDS, LTD.**
**HOBSON, H. M., LTD.**
Signal arm, rods, gearboxes.
**LUCAS, JOSEPH, LTD.**
Recirculating ball threads.
**METROPOLITAN-VICKERS ELECTRICAL CO., LTD.**
Activating mechanisms, control gear.
**NAPIER, D., and SON, LTD.**
Mechanisms.
**RENOLD CHAINS, LTD.**
Suspension chains.
**SALFORD ELECTRICAL INSTRUMENTS, LTD.**
Systems engineering.
**SCREW MACHINE PRODUCTS, LTD.**
Components.
**TELEFLEX PRODUCTS, LTD.**
Drives.
**T.I. NUCLEAR ENGINEERING, LTD.**
Tubular components.
**VICKERS-ARMSTRONGS (ENGINEERS), LTD.**
Actuating machinery.
**VICKERS NUCLEAR ENGINEERING, LTD.**
Mechanisms.

## 139 COOLERS

**CARRIER ENGINEERING CO., LTD.**
Air, water.
**DAVENPORT ENGINEERING CO., LTD., THE.**
Water.
**FIRTH BLAKELEY SONS AND CO., LTD.**
**LACY-HULBERT AND CO., LTD.**
After-coolers.
**LIGHTFOOT REFRIGERATION CO., LTD., THE.**
Water; packaged.
**PEABODY, LTD.**
Gas.
**PREMIER COOLER AND ENGINEERING CO., LTD., THE.**
Water, air, hydrogen, oil.
**SERCK RADIATORS, LTD.**
Air, gas.
**SPIRAL TUBE AND COMPONENTS CO., LTD., THE.**
Oil, water.
**SUPERHEATER CO., LTD., THE.**
Air.
**THERMO ENGINEERS, LTD.**
**VISCO ENGINEERING CO., LTD., THE.**
Water.

## 140 COOLING TOWERS

**BROTHERHOOD, PETER, LTD.**
**COOLING TOWERS, LTD.**
Designers.
**FILM COOLING TOWERS (1925), LTD.**
Natural, induced draught.
**HEAD WRIGHTSON PROCESSES, LTD.**
**MIDLAND HEATING AND VENTILATION CO., LTD., THE.**
Aquamiser evaporative.
**MITCHELL CONSTRUCTION CO., LTD., THE.**
**TILEMAN AND CO. LTD.**
**UNIVERSAL ASBESTOS MNFG. CO., LTD., THE.**
Pipes, fitments.
**YORKSHIRE ENGINEERING AND WELDING CO. (BRADFORD), LTD.**

## 141 CORE, REACTOR, RESTRAINT

**FAIREY AVIATION CO., LTD., THE.**
Links.
**HALL ENGINEERING, LTD.**
Equipment; charge pans.
**HALL, MATTHEW, AND CO., LTD.**
Installation; support, thermal shielding.
**NEWBURGH ENGINEERING CO., LTD.**
Charge pans.
**TALBOT STEAD TUBE CO., LTD.**
**T.I. NUCLEAR ENGINEERING, LTD.**

## 142 CORROSION PROTECTION

**ALLWEATHER PAINTS, LTD.**
Special coatings.
**ATLAS COPCO (GREAT BRITAIN), LTD.**
Spraying equipment.
**ANDRE RUBBER CO., LTD., THE.**
Tank, pipe rubber linings.
**ASHMORE, BENSON, PEASE AND CO.**
Metal spraying.
**BERK, F. W., AND CO., LTD.—SCHORI DIVISION.**
Metal, plastics, spraying equipment, painting.
**BETEL PRODUCTS, LTD.**
"Atomicote" chlorinated rubber paint, zinc primer.
**BITULAC, LTD.**
Paints.
**BRAMAH, J. R., AND CO., LTD.**
**BRISTOL METAL SPRAYING AND WELDING CO., LTD., THE.**
Metal-sprayed coatings.
**BRITISH PAINTS, LTD.**
"B.P.L. strippable paint."
**CHEMICAL ENGINEERING CONSTRUCTION (PENSNETT), LTD.**
Rubber-lined plant.

## 142 CORROSION PROTECTION (contd.)

**CHROME-ALLOYING CO., LTD., THE.**
Chrome-alloying mild steel.
**C. AND P. DEVELOPMENT CO. (LONDON), LTD.**
Cold galvanizing.
**DAVEY, PAXMAN AND CO., LTD.**
Metal spraying.
**DELORO STELLITE, LTD.**
Cobalt-chromium-tungsten "Stellite" alloys.
**EDWARDS HIGH VACUUM, LTD.**
Vacuum coating.
**ENGLAND HUGHES BELL AND CO., LTD.**
"Ceramite" epoxide finishes, "Cerapitch" coating.
**EVODE, LTD.**
Bituminous, aluminium, epoxy, resin, paints.
**EXTRUDEX, LTD.**
PVC, fibre-glass tank linings.
**FESCOL, LTD.**
Electro-deposition, nickel, chromium.
**FIBRECLAD, LTD.**
Plastics linings; on-site service.
**GARTHWOOD CO., LTD.**
Metal protectives, hot-dip, cold (strippable).
**GILMER, GERALD, LTD.**
Metal spraying.
**GRINDLAY, JAS., AND CO., LTD.**
Metal sprayers; painters.
**HARPER, JOHN, AND CO., LTD.**
Enamelling, plating, painting.
**HAWKER SIDDELEY NUCLEAR POWER CO., LTD.**
Hot, vapour-phase plating.
**HEAT TRANSFER, LTD.**
Metal spraying.
**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
Paints.
**INDUSTRIAL PAINTING CONTRACTORS (WINCHESTER), LTD.**
Metal spraying, neoprene coatings.
**JABLO PLASTICS INDUSTRIES, LTD.**
Jablo denswood.
**LEIGH, W. AND J., LTD.**
Specialized paint products.
**LEYLAND PAINT AND VARNISH CO., LTD.**
Protection, specialized paints.
**LONDON ALUMINIUM CO., LTD., THE.**
Hot anodizing, electro, chemical brightening.
**METAL AND PIPELINE ENDURANCE, LTD.**
Cathodic protection services.
**METAL SPRAYERS, LTD.**
Hot, metal protective coatings.
**METALLISATION, LTD.**
Metal, plastic spraying equipment; at works, on site service.
**METAL DEPOSITS, LTD.**
Metal spraying, painting, on site, own works.
**METALLIZING EQUIPMENT CO., LTD.**
Metal, ceramic spraying, hard-facing equipment, alloys.
**MURRAY AND RAMSDEN, LTD.**
Ebonite, soft rubber linings.
**NORTH BRITISH CHEMICAL CO., LTD.**
Paints.
**NORTON GRINDING WHEEL CO., LTD.**
Oxide coatings for metals, graphite.
**PINCHIN, JOHNSON AND CO.**
Metallic, bituminous paints.
**PRODORITE, LTD.**
Acid-proofing.
**PROTECTIVE RUBBER COATINGS (BRISTOL) LTD.**
Synthetic rubber coatings.
**RUSTLESS IRON CO., LTD., THE.**
Vitreous enamelling.
**ST. HELENS CABLE AND RUBBER CO., LTD.**
Rubber, plastics, linings, "Cabtyrit" paint.
**STEEL, J. M., AND CO., LTD.**
"Gloscoat," hot-dip plastics coating.
**TANKS AND LININGS, LTD.**
Coatings, acid resisting.
**TELEGRAPH CONDENSER CO., LTD., THE.**
**TOOLCHROME, LTD.**
Hard chromium, electro-depositors.
**TRETOL, LTD.**
Paints, plastics, coatings; strippable, non-strippable.
**UNITED INSULATOR DIVISION.**
"Unikote" ceramic coatings.
**UNIVERSAL METAL SPRAYERS, LTD.**
Metal spraying.
**WAILES, DOVE BITUMASTIC, LTD.**
Bitumastic solutions, enamels.
**YORKSHIRE METAL SPRAYERS, LTD.**
Metal sprayers (Schoop process).

## 143 COUPLINGS

**AIRTECH, LTD.**
Nylon, brass.
**AVICA EQUIPMENT, LTD.**
High pressure swivel joint.
**B.E.N. PATENTS, LTD.**
"Instantair" quick action.
**BLOCTUBE CONTROLS, LTD.**
"Bloctube" ball joints
**BRITISH ERMETO CORPORATION, LTD.**
Pipe, steel, s.s., brass, light alloy.
**BROWN, DAVID, INDUSTRIES, LTD.**
**CLAY CROSS (IRON FOUNDRIES), LTD.**
Flexible pipe joints.
**CLAYTON-WRIGHT, HOWARD, LTD.**
Clayflex.
**COLLIER AND COLLIER, LTD.**
Hose clips.
**CROFTS (ENGINEERS), LTD.**
**DICK, R. AND J., LTD.**
"Dickdrive C.L."; flexible.
**DIXON-BATE, B., LTD.**
Vacuum.
**DRAYTON REGULATORS AND INSTRUMENT CO., LTD.**
Bellows.
**ELECTRO DYNAMIC CONSTRUCTION CO., LTD.**
Magnetic.
**FLIGHT REFUELLING, LTD.**
Clear-bore, for charge machines, standpipes.
**GEARTIGHT UNIONS, LTD.**
Remotely operable pipe.
**GUYSON INDUSTRIAL EQUIPMENT, LTD.**
Hose (quick action); Hansen (A).
**HATHAWAY, L., LTD.**
Pipe.
**HIGH-PRESSURE COMPONENTS, LTD.**
**HOWARD MECHANICAL DEVELOPMENTS, LTD.**
Magnetic.
**I.V. PRESSURE CONTROLLERS, LTD.**
Leak-proof; pipe joints.
**KINGS LANGLEY ENGINEERING CO., LTD.**
"Kingley" copper.
**MACDONALD, JOHN, AND CO. (PNEUMATIC TOOLS), LTD.**
"Macdonald" quick-action hose.
**METALASTIK, LTD.**
Flexible.
**MOLLART ENGINEERING CO., LTD., THE.**
Universal joints; drive shafts.
**N.G.N. ELECTRICAL, LTD.**
Vacuum, demountable, unions.
**OIL FEED ENGINEERING CO., LTD.**
Self sealing, special.
**POWER AUXILIARIES, LTD.**
Flexible.
**SILENTBLOC, LTD.**
Flexible.
**SIMPLIFIX COUPLINGS, LTD.**
Compression.
**STEWARTS AND LLOYDS, LTD.**
Pipe, tube.
**TALBOT STEAD TUBE CO., LTD.**
Tube fittings.
**TWIFLEX COUPLINGS, LTD.**
Flexible.
**UNITED FLEXIBLE METALLIC TUBING CO., LTD., THE.**
Tube.
**VICTAULIC CO., LTD., THE.**
Flexible joints for steel, c.i., concrete pipes.
**WADE COUPLINGS, LTD.**
Pipe, (compression type), metal, plastic.
**WALKER, C. AND W., LTD.**
Pipe.
**WIGGLESWORTH, FRANK, AND CO., LTD.**
Flexible.
**WOOD BROS. AND CO. (GASKETS), LTD.**
Pipe, metal, asbestos.

## 144 CRANES

*see also LIFTING GEAR*

**ADAMSON, JOSEPH, AND CO., LTD.**
Electric, overhead travelling.
**ANDREWS AND PLATT (ENGINEERS), LTD.**
**ARROL, SIR WILLIAM, AND CO., LTD.**
**BABCOCK AND WILCOX, LTD.**
**BARNSLEY, JOHN, AND SONS, LTD.**
Overhead travelling.
**BRITISH INDUSTRIAL ENGINEERING CO., LTD.**
Travelling, revolving, overhead, goliath.
**BUTTERLEY CO., LTD., THE.**
Electric overhead travelling.
**BUTTERS BROS. AND CO., LTD.**
Cranes, derrick, monotower, overhead, winches.
**CARRUTHERS, J. H., AND CO., LTD.**
E.O.T., goliath.
**CLYDE CRANE AND BOOTH, LTD.**
Goliath, monotower, overhead, travelling.
**COWANS, SHELDON AND CO., LTD.**
Overhead, jib, goliath; turntables.
**FELCO HOISTS, LTD.**
**FELLOWS BROS., LTD.**
Electric, hand-operated, overhead, travelling.
**HENDERSON, JOHN M., AND CO., LTD.**
Derrick, overhead.
**HEYWOOD, S. H., AND CO., LTD.**
Overhead; traversers, transporters.
**IRBING ENGINEERING CO., LTD.**
Overhead, travelling; conveyors, elevators.
**KING, GEO. W., LTD.**
**K. AND L. STEELFOUNDERS AND ENGINEERS, LTD.**
Mobile to 20 tons.
**LAMBERT ENGINEERING CO. (GLASGOW), LTD.**
Mobile, 3–10 tons.
**LEES, HENRY, AND CO., LTD.**
E.O.T.
**MATTERSON, LTD.**
Overhead travelling.
**MORRIS, HERBERT, LTD.**
Hand and electric jib-cranes.
**PARKER MITCHELL ENGINEERING CO., LTD.**
Special hoisting machinery.
**PATERSON HUGHES ENGINEERING CO., LTD.**
Electric, overhead, travelling.
**RANSOMES AND RAPIER, LTD.**
Mobile.
**RICHARDSON, R. J., AND SONS, LTD.**
(A).
**SMITH, THOS., AND SONS (RODLEY), LTD.**
Locomotive, truck-mounted, gantry, crawler.
**STEELS ENGINEERING PRODUCTS, LTD.**
"Coles" self-propelled, truck-mounted, 5 to 50 tons.
**STOTHERT AND PITT, LTD.**
Gantry; special overhead; jib.
**VAUGHAN CRANE CO., LTD., THE.**
Overhead travelling, traversers; specials.
**WHARTON CRANE AND HOIST CO., LTD., THE.**
Overhead, electric, travelling; hand.
**WICKHAM ENGINEERING CO., LTD.**
**WILD, THOS. C., (MACHINERY), LTD.**
Tower, electric, rail-mounted, overhead.

## 145 CUTTING MACHINES

**BADDELEY, D. S., ENG. CO., LTD.**
Acetylene.
**BRITISH OXYGEN GASES, LTD.**
**B.S.A. TOOLS, LTD.**
Research, development.
**CENTRAJET, LTD.**
"Centrajet" oxygen nozzles, "Hi-Lo" hand.
**HANCOCK AND CO. (ENGINEERS), LTD.**
Oxygen (all types).
**LINCOLN ELECTRIC CO., LTD.**
"Arcair" equipment.
**MOUNTFORD, JOHN, AND CO., LTD.**
Components.
**OXHYCARBON CO., LTD.**
**WELDING SUPPLIES, LTD.**
O.K. oxygen.
**YOUNG, A. S., AND CO., LTD.**
Equipment; oxy-acetylene.

## 146 CYCLONES

**AIR CONTROL INSTALLATIONS, LTD.**
Dry.
**BRAMAH, J. R., AND CO., LTD.**
**DAVIDSON AND CO., LTD.**
Dry.
**HOLMES, W. C., AND CO., LTD.**
**JOHNSTONE, ARCHIBALD (ENGINEERS), LTD.**
Dry.
**MANCUNA ENGINEERING, LTD.**
**POWER-GAS CORPORATION, LTD., THE.**
Wet.
**RICHARDSON, W., AND CO., LTD.**
**SIMON-CARVES, LTD.**
Dry.
**THERMIX INDUSTRIES, LTD.**
High-efficiency.
**VICKERYS, LTD.**
**YORKSHIRE ENGINEERING AND WELDING CO. (BRADFORD), LTD.**
Dry, wet.

# D

## 147 DEMINERALIZATION PLANT

*see also WATER TREATMENT, EFFLUENT TREATMENT*

**WILLIAM BOBY AND CO., LTD.**
**ELGA PRODUCTS, LTD.**
"Elgastat" deionizers.
**PATERSON ENGINEERING CO., LTD., THE.**
Ion exchange.
**PERMUTIT CO., LTD., THE.**
**THOMPSON-KENNICOTT, JOHN, LTD.**

## 148 DOORS

**ARMSTRONG PATENTS CO., LTD.**
"Strongarm" closers.
**BARKER, JOHN, AND SONS (ENGINEERS), LTD.**
Fire, folding; rolling shutters.
**BOLTON GATE CO., LTD., THE.**
Folding shutter, collapsible, fireproof.
**BRADY, G., AND CO., LTD.**
Rolling, sliding shutter, fireproof.
**COBURN ENGINEERS, LTD.**
Gear.
**CURFEW DOORS AND SHUTTERS, LTD.**
Fireproof, steel, rolling, collapsible.
**FOX, FREDERICK, LTD.**
Fire resisting.
**HAYWARDS, LTD.**
Steel.
**THORNBOROUGH AND SON (MANCHESTER), LTD.**
Sliding, fireproof; roller shutters, collapsible gates.
**WALKER, C. AND W., LTD.**
Heavy shielding.
**WEST'S GAS IMPROVEMENT CO., LTD**
Electrically operated shield.
**WESTWOOD, JOSEPH, AND CO., LTD.**
Solid steel.

## 149 DRIVES

**ARENS CONTROLS, LTD.**
Remote; push, pull, transmission.
**BRITISH ELECTRICAL REPAIRS, LTD.**
Ward Leonard sets to 10 kW.
**BROWN, DAVID, INDUSTRIES, LTD.**
Variable speed.
**BROWN, DAVID, CORPORATION (SALES), LTD.**
"Varicon" stepless speed reducers.
**CROFTS (ENGINEERS), LTD.**
Variable speed, reduction gears.
**DICK, R. AND J., LTD.**
Belts.
**ELECTRICAL POWER ENGINEERING CO. (B'HAM), LTD., THE.**
Ward Leonard sets.
**FLUIDRIVE ENGINEERING CO., LTD.**
Vulcan-Sinclair variable speed fluid self-synchronizing clutches.
**LANCASHIRE DYNAMO NEVELIN, LTD.**
Variable speed.
**METADUCTS, LTD.**
Power transmission.
**MORRIS, B. O., LTD.**
Flexible shaft.
**M.T.E. CONTROL GEAR, LTD.**
Variable speed.
**NELSON ENGINEERING CO., LTD., THE.**
Variable speed.
**SAUTER CONTROLS, LTD.**
Motorised.
**VACUUM RESEARCH (CAMBRIDGE), LTD.**
H.P., variable speed hydraulic.
**VICKERS-ARMSTRONGS (ENGINEERS), LTD.**
Hydraulic variable speed; gear.
**WESTOOL, LTD.**
**WIGGLESWORTH, FRANK, AND CO., LTD.**
V-belt, variable speed.

## 150 DRYING PLANT

*see also AIR CONDITIONING*

**BIRLEC, LTD.**
Instrument, hydrogen, compressed air, $CO_2$.
**BUELL (1952), LTD.**
Rotary, turbo, spray.
**BURNETT AND LEWIS, LTD.**
Argon, $CO_2$, compressed air.
**CALMIC ENGINEERING CO., LTD.**
Vacuum, stainless steel for Beryllium, Zirconium.
**HOLMES, W. C., AND CO., LTD.**
Air.
**HUNT AND MOSCROP, LTD.**
**MITCHELL, L. A., LTD.**
**PORTER, ALFRED, AND CO., LTD.**
Air, "Humiditrol."
**SIMON, RICHARD, AND SONS, LTD.**
**SILICA GEL, LTD.**
Silica gel dehumidification desiccants.
**TOMLINSONS (ROCHDALE), LTD.**
"Drydapta" machines.
**WEATHERFOIL HEATING SYSTEMS, LTD.**
Air.

## 151 DUCTING

**ACALOR (1948), LTD.**
Plastics fabricated.
**AIR CONTROL INSTALLATIONS, LTD.**
**AITON AND CO., LTD.**
**ALLEN, ALFRED, AND SON, LTD.**
**ASHMORE, BENSON, PEASE AND CO.**
**BABCOCK AND WILCOX, LTD.**
**BIRWELCO, LTD.**
**BRABY, FREDERICK, AND CO., LTD.**
**BRAMAH, J. R., AND CO., LTD.**
Metallic.
**CHEMIDUS PLASTICS, LTD.**
Plastics.
**DAVEY, PAXMAN AND CO., LTD.**
**EXTRUDEX, LTD.**
Acid resistant.
**FLEXIBLE DUCTING, LTD.**
Flexible; ventilation.
**GARDNER, J., AND CO., LTD.**
Air.
**HALL BROTHERS (NETHERTON), LTD.**
**INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.**
**JENKINS, ROBERT, AND CO., LTD.**
M.S.; $CO_2$.
**JOHNSTONE, ARCHIBALD (ENGINEERS), LTD.**
**LONGCLOSE ENGINEERING CO., LTD.**
S.s.
**MOORE, J. AND E., LTD.**
**MOTHERWELL BRIDGE AND ENGINEERING CO., LTD., THE.**
Lloyd's Class 1; other specifications.
**NEILL, WM., AND SON (ST. HELENS), LTD.**
Chimney, large diameter piping.
**PEARSON, T. B., AND SONS, LTD.**
**PARSONS, C. A., AND CO., LTD.**
**PIPE FABRICATORS (STAMFORD), LTD.**
Steel chimneys, flues.
**REDHEUGH IRON AND STEEL CO. (1936), LTD.**
**RESISTANT EQUIPMENT, LTD.**
Plastics.
**RICHARDSON, W., AND CO., LTD.**
Aluminium, sheet steel.
**SIMON-CARVES, LTD.**
**STAINLESS STEEL PROFILE CUTTERS, LTD.**
**STIRLING, R. B., AND CO., LTD.**
**SUPERVENTS, LTD.**
**THOMPSON, JOHN, LTD.**
**TUPHOLME, GEORGE E., AND CO., LTD.**
Ventilation; air; dampers.
**WESTWOOD, JOSEPH, AND CO., LTD.**
**X-LON PRODUCTS.**
Plastics.
**YARROW AND CO., LTD.**
**YORKSHIRE ENGINEERING AND WELDING CO. (BRADFORD), LTD.**

## 152 DUST REMOVAL

*see also AIR CONDITIONING, CYCLONES, ELECTROSTATIC SEPARATORS*

**ACME VENTILATING, LTD.**
**BUELL (1952), LTD.**
**DALLOW LAMBERT AND CO., LTD.**
Dry, wet, installations.
**DAVIDSON AND CO., LTD.**
Mechanical, electrostatic.
**DUSTRACTION, LTD.**
**GUYSON INDUSTRIAL EQUIPMENT, LTD.**
**HOLMES, W. C., AND CO., LTD.**
Control plant.
**MANCUNA ENGINEERING, LTD.**
**MIDLAND HEATING AND VENTILATION CO., LTD., THE.**
"Midac" dust, fume control.
**NEW WELBECK, LTD.**
Portable suction cleaners.
**PULVERIZING MACHINERY, LTD.**
"Mikro Pulsaire."
**SPENCER AND HALSTEAD, LTD.**
Exhaust systems.
**STURTEVANT ENGINEERING CO., LTD.**
Units, portable.
**SUPERVENTS, LTD.**
**THERMIX INDUSTRIES, LTD.**
"Airmix" wet; "Tubix" multitubular.
**VISCO ENGINEERING CO., LTD., THE.**
**WEATHERFOIL HEATING SYSTEMS, LTD.**

# E

## 153 EFFLUENT TREATMENT

*see also WATER TREATMENT*

**ALLEN, EDGAR, AND CO., LTD.**
Crushing equipment.
**BOBY, WILLIAM, AND CO., LTD.**
**CHEMICAL ENGINEERING CONSTRUCTION (PENSNETT), LTD.**
Plant.
**EKCO ELECTRONICS, LTD.**
Monitors.
**FULLER'S EARTH UNION, LTD., THE.**
Cation-exchanging clays.
**HEAD WRIGHTON PROCESSES, LTD.**
Active waste incinerators.
**MAITLANDS (METAL WORKS), LTD.**
Stainless steel tanks.
**MENDIP (CHEMICAL ENGINEERING), LTD.**
Waste, delay tanks.
**MOORES (BOURNEMOUTH), LTD.**
Active waste, sorting cabinets.
**MUNRO, R. W., LTD.**
Discharge anemometers.
**PATERSON ENGINEERING CO., LTD., THE.**
General plant.
**PERMUTIT CO., LTD., THE.**
Ion exchange plant.
**PHILIPS ELECTRICAL, LTD.**
Liquid clarification.
**PRODORITE, LTD.**
Drainage schemes.
**SIMON-CARVES, LTD.**
Complete plants.
**SUTCLIFFE, SPEAKMAN AND CO., LTD.**
Activated carbon, stampings, solvent recovery plants.
**THOMPSON-KENNICOTT, JOHN, LTD.**
Trade, active waste.
**THOMPSON, JOHN, LTD.**

## 154 ELECTRICAL, ELECTRONIC COMPONENTS

**ABLE ENGINEERING CO., LTD.**
Magnetic amplifiers; transductors 0–10 kVA; constant current, voltage supplies.
**ACRU ELECTRIC TOOL MFG. CO., LTD., THE.**
Soldering irons.
**ADCOLA PRODUCTS, LTD.**
Soldering equipment.
**ADVANCE COMPONENTS, LTD.**
Constant-voltage transformers; attenuators.
**A.E.W., LTD.**
Wirewound resistors; circuit breakers.
**ALL-POWER TRANSFORMERS, LTD.**
Power supplies, transformers, toroidal winding; wirewound resistors.

## 154 ELECTRICAL, ELECTRONIC COMPONENTS (contd.)

**AMPLIVOX, LTD.**
Communication systems.

**ANDEC, LTD.**
Transformers, smallest to 50 kVA.

**A.N.T.E., LTD.**
Miniature soldering irons.

**ANTICOUSTIC CO., LTD.**
Acoustic equipment.

**ASSOCIATED ELECTRICAL INDUSTRIES, LTD.**
Power rectifiers.

**ATKINS, ROBERTSON AND WHITEFORD, LTD.**
Transformers, pulse-forming networks, delay lines.

**AUSTIN TAYLOR ELECTRICAL, LTD.**
Terminals, cable glands.

**AVELEY ELECTRIC, LTD.**
Toroidally-wound transformers, transductors, inductors, reactors, filters.

**BELCLERE CO., THE.**
Transformers, chokes.

**BESSON AND ROBINSON, LTD.**
Relays; coaxial plugs, sockets; timing units.

**BRITISH CENTRAL ELECTRICAL CO., LTD.**
Storage units, relays.

**BRITISH INSULATED CALLENDER'S CABLES, LTD.**
Capacitors.

**BRITISH PHYSICAL LABORATORIES.**
Meters—multi-range, hermetically sealed digital.

**BRITISH THOMSON-HOUSTON CO., LTD., THE.**
Regulators.

**BROWN, S. G., LTD.**
Potentiometers, power packs, inductive pick-offs.

**BROWNINGS ELECTRIC CO., LTD.**
Soldering irons, coil winding, regulators, actuators.

**BRUSH CRYSTAL CO., LTD.**
Piezoelectric, ferroelectric, paramagnetic, crystals, semi-conductors.

**BRYANS AEROQUIPMENT, LTD.**
Pressure, acceleration, displacement, temperature transducers.

**BRYCE ELECTRIC CONSTRUCTION CO., LTD.**
Capacitors, transformers, current limiting reactors.

**BULGIN, A. F., AND CO., LTD.**
Connectors, holders, plugs, etc.

**CABLEFORM, LTD.**
Contactor gear; cable assemblies.

**C.N.S. INSTRUMENTS, LTD.**
A.C. mains stabilizer.

**COX-WALKERS, LTD.**
Regulators.

**CRAIG AND DERRICOTT, LTD.**
Indicator lamps.

**CRESSALL MFG. CO., LTD., THE.**
Rheostats, potentiometers, auto-transformers.

**CROMPTON PARKINSON, LTD.**
Transformers, lighting.

**C.W.C. EQUIPMENT, LTD.**
Connectors, wiring systems.

**DALY (CONDENSERS), LTD.**
Electrolytic capacitors.

**DAVIS, JOHN, AND SON (DERBY), LTD.**
Relays, transformers, signalling f.l.p. equipment.

**DEPENDABLE RELAY CO., LTD.**
Relays.

**DONOVAN ELECTRICAL CO., LTD., THE.**
Relays, contactors, starters, control panels.

**D.S. PLUGS, LTD.**
Plugs, sockets.

**DUBILIER CONDENSER CO. (1925), LTD.**
Capacitors; carbon, wire-wound resistors.

**ELECTRO DYNAMIC CONSTRUCTION CO., LTD.**
Converters, regulators.

**ELECTRONIC TUBES, LTD.**
Industrial cathode ray tubes.

**E.M.B. CO., LTD.**
Resistances.

**ENGLISH ELECTRIC VALVE CO., LTD.**
Rectifiers, valves, klystrons, travelling wave tubes.

**EXPANDED METAL CO., LTD., THE.**
Resistors, voltage stabilizers..

**EXPRESS TRANSFORMERS AND CONTROLS, LTD.**
Transformers to 500 kVA specials.

**FAIREY AVIATION CO., LTD., THE.**
Actuators; automatic soldering; looms; printed potted circuits.

**FALK, STADELMANN AND CO., LTD.**
Vapour, corrosion resistant, lighting fittings; cables.

**FARNELL INSTRUMENTS, LTD.**
Transistor power supplies, fuel meters, design, manufacturing.

**FIELDEN ELECTRONICS, LTD.**
D.C. amplifier, differential transformers.

**FORTIPHONE, LTD.**
Miniature transformers, controls, connectors.

**FOX, P. X., LTD.**
Potentiometers.

**FRASER, SPELLER TRANSFORMERS, LTD.**
Transformers, chokes.

**FULLER ELECTRIC, LTD.**
Transformers, tap changers.

**GARDNERS RADIO, LTD.**
Transformers, chokes.

**GLOSTER AIRCRAFT CO., LTD.**
Transducers.

**GOODMANS INDUSTRIES, LTD.**
Loudspeakers, chokes, ion traps, vibration generators.

**GRESHAM TRANSFORMERS, LTD.**
Transformers, voltage regulators, electronics to custom requirements.

**HACKBRIDGE AND HEWITTIC ELECTRIC CO., LTD.**
Transformers, rectifiers, chargers.

**HADLEY TELEPHONE AND SOUND SYSTEMS, LTD.**
Amplifiers, panels, communication systems.

**HELLERMANN, LTD.**
Compression terminals, tools, plugs, sockets.

**HOLIDAY AND HEMMERDINGER, LTD.**
(A).

**HUNT, A. H., (CAPACITORS), LTD.**
Capacitors.

**IGRANIC ELECTRIC CO., LTD.**
Starters, contactors, relays, transformers.

**INGLIS KNIBB AND CO.**
Elmeco electro magnetic pulse counters.

**ISENTHAL AND CO., LTD.**
Regulators, relays, rheostats, resistances.

**JOBLING, JAMES A., AND CO., LTD.**
Metal oxide film resistors.

**JOHNSON AND PHILLIPS, LTD.**
Transformers, capacitors.

**JONES, J., AND CO. (NOTTINGHAM), LTD.**
Repairs, rewinds, specials.

**JONES, WALTER, AND CO. (ENGINEERS), LTD.**
Transformers, converters, inverters, special equipment.

**K.D.G. INSTRUMENTS, LTD.**
Transducers.

**KINGSTON INSTRUMENT CO., LTD.**
Special mechanical, electro-mechanical equipment.

**KLAXON, LTD.**
Audible signals, alarms.

**LANGHAM, THOMPSON, J., LTD.**
Transducers, recording cameras, voltage supplies, potentiometers.

**LONDEX, LTD.**
Relays, timers.

**M. B. METALS, LTD.**

**MAGNETIC DEVICES, LTD.**
Relays, contactors.

**MAGNETIC AND ELECTRICAL ALLOYS, LTD.**
Silicon steel, nickel alloys; magnetic shields.

**McGEOCH, WILLIAM, AND CO., LTD.**
Plugs, sockets, bakelite mouldings light fittings.

**McMURDO INSTRUMENT CO., LTD., THE.**
Valveholders, plugs, sockets, special mouldings.

**MEGATRON, LTD.**
Selenium photo cells.

**MERITUS (BARNET), LTD.**
Battery chargers, rectifiers, transformers, impedance testers.

**MINING AND CHEMICAL PRODUCTS, LTD.**
Semi-conductors.

**MORRIS, JOHN, ELECTRICAL ENG. CO., LTD.**
Regulators, stabilizers, relays, contactors.

**M-O VALVE CO., LTD., THE.**
Thermionic valves; cathode ray tubes.

**MULLARD, LTD.**
Thermionic valves, tubes; semiconductor-devices.

**NALDER BRO. AND THOMPSON, LTD.**
Relays.

**NELSON ENGINEERING CO., LTD., THE.**
Transformers, rectifier equipment, regulators.

**NELSON, W. AND H., LTD.**
Starters, auto transformers, controllers, resistances.

**NEWMARKET TRANSISTORS, LTD.**
Semi-conductor devices, transistors.

**NEWPORT INSTRUMENTS (SCIENTIFIC MOBILE), LTD.**
Current-stabilized power supplies, ferrite cores.

**NEWTON BROS. (DERBY), LTD.**
Regulators, transformers, invertors, alternators.

**N.S.F., LTD.**
Carbon potentiometers, connectors.

**PAINTON AND CO., LTD.**
Fixed, adjustable, wirewound, carbon resistors; potentiometers.

**P.A.M., LTD.**
Transformers, closed-circuit television equipment.

**PARSONS, C. A., AND CO., LTD.**
Transformers.

**PELL, OLIVER, CONTROL, LTD.**
Chokes, coils, relays (A), transformers; transistors (A).

**PLESSEY CO., LTD., THE.**
Plugs, sockets, connectors, transformers, transductors, switches, relays, actuators.

**PRINTED CIRCUITS, LTD.**
Printed circuits, cable forms, units.

**READ AND PARTNERS, LTD.**
Lightning, static protection.

**RECORD ELECTRICAL CO., LTD., THE.**
Relays, transformers, test sets.

**REDCLIFFE RADIO AND ENGINEERING CO., LTD., THE.**
Transformers, chokes, etc.

**RESEARCH AND CONTROL INSTRUMENTS, LTD.**
Barretters, chargers, ignitrons, rectifiers, transformers, stabilizers, etc.

**RIVLIN INSTRUMENTS, LTD.**
Resistors, precision wirewound.

**ROSS, COURTNEY AND CO., LTD.**
Wiring accessories.

**SANGAMO WESTON, LTD.**
Panel meters.

**SAUTER CONTROLS, LTD.**
Contactors, relays.

**SCOTT, HUGH J., AND CO. (BELFAST), LTD.**
A.C., d.c. equipment.

**SEMICONDUCTORS, LTD.**
Transistors.

**SERVOMEX CONTROLS, LTD.**
Voltage stabilizers.

**SIMMONDS, L. E., LTD.**
Relays, transformers.

**SMITHS INDUSTRIAL INSTRUMENT DIVISION.**
Magnetic, electric tachometers, calibrated relays.

**SOLARTRON ELECTRONIC GROUP, LTD.**
Power supplies.

**SOUND INDUSTRIES.**
Transformers.

**SOUTH WALES SWITCHGEAR, LTD.**
Power transformers.

**SPEAR ENGINEERING CO., LTD.**
Thermionic valve accessories, sub-miniature plugs, sockets.

**SPERRY GYROSCOPE CO., LTD.**
Transformers, integrators, tachogenerators.

**STERLING INSTRUMENT CO., LTD.**
Special electro-mechanical devices.

**STEWART AERONAUTICAL SUPPLY CO., LTD.**

**STONEBRIDGE ELECTRICAL CO., LTD., THE.**
Counters, electro-magnetic.

**STRATTON AND CO., LTD.**
VHF/UHF equipment.

**STURDY ELECTRIC CO., LTD.**
Transformers, transductors, magnetic amplifiers, regulators.

**TAYLOR ELECTRICAL INSTRUMENTS, LTD.**
Panel meters.

**TECHNOGRAPH ELECTRONIC PRODUCTS, LTD.**
Metal foil resistors, inductors, capacitors, wave guides, de-icing.

**TELECOMMUNICATION INSTRUMENTS, LTD.**
Microwave components, power units, test apparatus.

**TELEDICTOR, LTD.**
Transformers, chokes, sub-contract units.

**TELEGRAPH CONDENSER CO., LTD., THE.**
Capacitors.

**TELEGRAPH CONDENSER CO., LTD., THE, UNITED INSULATOR DIVISION.**
Ultrasonic transducers, accelerometers, condensers, insulators; development.

**TELEPHONE MANUFACTURING CO., LTD.**
High-voltage capacitors.

**TEXAS INSTRUMENTS, LTD.**
Rectifiers, transistors, semi-conductors.

**THORN ELECTRICAL INDUSTRIES, LTD.**
Relays, circuit breakers, connectors, lampholders.

**TRANSFORMER AND ELECTRICAL CO., LTD., THE.**
Transformers to 100 kVA, chokes, sub-assemblies.

**TRUVOX, LTD.**
Tape recorders, accessories.

## 154 ELECTRICAL, ELECTRONIC COMPONENTS (contd.)

**VACTRIC (CONTROL EQUIPMENT), LTD.**
Tachogenerators.

**VITALITY BULB, LTD.**
Miniature, sub-miniature bulbs.

**WALKER, C. AND W., LTD.**
Power supplies; Klystron, stabilized, transistor; interferometers.

**WAYMOUTH GAUGES AND INSTRUMENTS, LTD.**
Relays connectors.

**WELWYN ELECTRICAL LABORATORIES, LTD.**
Wirewound, carbon, high-value resistors; potentiometers.

**WESTOOL, LTD.**
Transformers, coils, amplifiers.

**WEYMOUTH RADIO MANUFACTURING CO., LTD.**
Coils, transformers.

**WILFLO PRODUCTS, LTD.**
Transformers, rectifiers.

**WINDER, R. F., LTD.**
Reconditioned.

**WINGROVE AND ROGERS, LTD.**

**WINSTON ELECTRONICS, LTD.**
Helical potentiometers; counters (A).

**YORKSHIRE ELECTRIC TRANSFORMER CO., LTD.**
Transformers.

**ZENITH ELECTRIC CO., LTD., THE.**
"Variac," Zenith transformers, inductances, wire-wound resistors, rheostats, flash testing, voltage regulators.

## 155 ELECTROSTATIC SEPARATORS

**DAVIDSON AND CO., LTD.**

**HOLMES, W. C., AND CO., LTD.**
Precipitators.

**RAPID MAGNETIC MACHINES, LTD.**

**STURTEVANT ENGINEERING CO., LTD.**
Precipitators.

## 156 ENGRAVING

**BUTLER RADIO MFG. CO. (ROCHESTER), LTD.**

**CAXTON NAME PLATE MFG. CO., LTD.**
Nameplates, dials, labels; metal, plastic.

**ELECTROMARK (G.B.), LTD.**
Electrolytic marking.

**GROVEMETAL MANUFACTURING CO., LTD.**
Dial manufacturers.

**METAL GRAVURE CO., LTD., THE.**
Nameplates, instrument dials, panels, adhesive.

**MILLETT, LEVENS (ENGRAVERS), LTD.**
Dials, scales; metals, plastics.

**PRECISION UNITS (DORSET), LTD.**
Labels, plates.

**THREADWELL, J. J., AND SONS, LTD.**

## 157 EXPANSION JOINTS
*see also BELLOWS*

**AITON AND CO., LTD.**

**BRITISH APPLIANCE MFG. CO., LTD.**
Steel, s.s.

**ENGINEERING APPLIANCES, LTD.**
Agents for I.W.K.

**INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.**

**JENKINS, ROBERT AND CO., LTD.**

**JOHNSTONE, ARCHIBALD (ENGINEERS), LTD.**

**LUCAS, JOSEPH, LTD.**
S.s., nimonic.

**MUNRO AND MILLER, LTD.**

**PALATINE TOOL AND ENGINEERING CO. (SURBITON), LTD.**

**POWER FLEXIBLE TUBING CO., LTD., THE.**

**STANTON IRONWORKS CO., LTD., THE.**
Pipes, prestressed concrete, spun concrete pipes.

**TEDDINGTON AIRCRAFT CONTROLS, LTD.**
Stainless steel.

**TEDDINGTON INDUSTRIAL EQUIPMENT, LTD.**

**WALKER, C. AND W., LTD.**

**WILSON PIPE FITTINGS, LTD.**

# F

## 158 FABRICATIONS

**AOCLES AND POLLOCK, LTD.**
Tubular reactor components.

**A.C.M. ELECTRONICS.**
Precision sheet metal work.

**ACME VENTILATING, LTD.**
Steel.

**ADAMSON, DANIEL, AND CO., LTD.**
Medium, heavy; pressure vessels; carbon, alloy steels.

**ADAMSON, JOSEPH, AND CO., LTD.**
Lloyd's class 1, welded pressure vessels.

**ALLEN, ALFRED, AND SON, LTD.**
Vessels, m.s.; stacks, hoppers, tanks.

**ALLEN, EDGAR, AND CO., LTD.**
Steel plate work.

**ALLEN, W. G., AND SONS (TIPTON), LTD.**
Steel, alloy, s.s., aluminium; to 10 tons.

**ALMIN, LTD.**
Aluminium pressing, spinning, welding.

**ANGLO-SWEDISH ELECTRIC WELDING CO., LTD., THE.**
Vessels, pipe lines, tank repair service.

**A.P.V. CO., LTD., THE.**
Aluminium, s.s.; reactor, core tanks.

**ARCHITECTURAL AND INDUSTRIAL MODEL CO., LTD.**
Models.

**AYRSHIRE DOCKYARD CO., LTD.**
S.s.; vessels, tanks.

**ASHMORE, BENSON, PEASE AND CO.**
Pressure vessels.

**ASSOCIATED NUTAL WORKS (GLASGOW), LTD.**
S.s., aluminium, tanks, pressure vessels, ducting.

**AUSTIN, JAMES, AND SONS (DEWSBURY), LTD.**
Steel; welded, riveted.

**AYLING NUCLEAR EQUIPMENT CO.**
Design; toolmaking; steel to 10 tons; plastics.

**BABCOCK AND WILCOX, LTD.**
Pressure vessels; containment vessels.

**BADDELEY, D. S., ENG. CO., LTD.**
Brazing.

**BAIN, W. B., AND CO., LTD.**
M.s.

**BALFOUR, HENRY, AND CO., LTD.**
Pressure vessels; m.s., s.s., clad, glass-lined.

**B.A.P. (WELDING ACCESSORIES DIV.), LTD.**
Aluminium, m.s., s.s., nimonics, titanium.

**BARNSLEY, JOHN, AND SONS, LTD.**
Steel.

**BAYLISS JONES AND BAYLISS, LTD.**
Steel to 50 tons, machining facilities.

**BELL PRECISION ENGINEERING CO., LTD.**
High precision.

**BENNIS COMBUSTION, LTD.**
M.s., s.s.; tanks, pressure vessels.

**BIRMINGHAM AND BLACKBURN CONSTRUCTION CO., LTD.**
Plate to ½ in.; m.s., s.s.; light alloys.

**BIRWELCO, LTD.**
Aluminium pressure vessels.

**BLAGDEN, VICTOR, AND CO., LTD.**
Steel drums; reconditioners.

**BRABY, FREDERICK, AND CO., LTD.**
Plate, sheet metal; vessels, tanks.

**BRAITHWAITE AND CO. ENGINEERS, LTD.**
Pressed steel tanks.

**BRAMAH, J. R., AND CO., LTD.**
Vessels, s.s., calandrias, tanks, bubble caps, trays.

**BRITISH ACHESON ELECTRODES, LTD.**
Corrosion resistant chemical plant.

**BRITISH APPLIANCES MFG. CO., LTD.**
Platework, tanks, vessels.

**BRITISH INDUSTRIAL ENGINEERING CO., LTD.**
Heavy, light; platework to 20 tons.

**BRITISH REFRASIL CO., THE.**
Light-gauge s.s.

**BROWN, E. G., AND CO., LTD.**
Precision engineering, s.s.

**BROWN, JOHN, AND CO., LTD.**
Steel, alloy, s.s. reactor pressure vessels.

**BUTTERLEY CO., LTD., THE.**
Welded, all types.

**BUTTERFIELD, W. P., LTD.**
Liquid gases storage vessels, m.s., s.s., Al, Mg.

**CAMBRIAN PLANT, LTD.**
Sheet metal work, light steel.

**CASS AND PHILLIP, LTD.**

**CASTON BARBER AND CO., LTD.**
Pressure, high-vacuum vessels.

**CENTRAX, LTD.**
Sheet metal work; design capacity.

**CHESTERFIELD TUBE CO., LTD., THE.**
Seamless steel headers, pressure vessels, cylinders.

**CHILLCOTTS, LTD.**
Light, medium sheet metal.

**CLARKE, CHAPMAN AND CO., LTD.**
Pressure vessels.

**C. AND M. ENGINEERING CO., LTD.**
Welded m.s., ¼-in plate to 5 tons.

**COCHRAN AND CO. ANNAN, LTD.**
Pressure vessels.

**COLVIN-SMITH, LTD.**
Steelwork.

**CORNERCROFT, LTD.**
Sheet metal spinnings, pressings.

**COVENTRY RADIATOR AND PRESSWORK CO., LTD.**
Pressings, sheet metal

**CRADLEY BOILER CO., LTD.**
Cylindrical vessels, air receivers.

**CRAVEN BROTHERS (MANCHESTER), LTD.**
Steel; heat treatment.

**CRAVENS, LTD.**
S.s. pipework, pressure vessels.

**CRITTALL-LUXFER, LTD.**
Aluminium; steel vessels to ¼-in. plate.

**CROFTS (ENGINEERS), LTD.**
Steel.

**CUPROCYL, LTD.**
Non-ferrous tanks.

**DARHAM INDUSTRIES (LONDON), LTD.**
S.s., m.s., monel, aluminium vessels, tanks.

**DAVEY, PAXMAN AND CO., LTD.**
Aluminium, steel, s.s.; clad, lead lined.

**DAVISON AND CO. (HEXHAM), LTD.**

**DELANEY GALLAY, LTD.**
S.s. from 0.004 in.; aluminium brazing.

**DENDY, RICHARD, AND ASSOC.**
Model makers.

**DISTINGTON ENGINEERING CO., LTD.**
Heavy steel self-supporting chimneys.

**ELECTRO-HYDRAULICS, LTD.**
Vessels, s.s.

**EMPYRIUM WELDING-MFG CO., LTD.**
Pressure vessels, $CO_2$ receivers, ductwork.

**ENGELHARD INDUSTRIES, LTD.**
Precious metal.

**EVANS, J., AND SON (PORTSMOUTH), LTD.**
S.s., components, assemblies.

**FAIREY AVIATION CO., LTD., THE.**
Aluminium alloy; gas systems; in-pile loops.

**EDWARD FARR, LTD.**
Welded steel plate; rolled sections.

**FARRAR BOILERWORKS, LTD., THE.**
Welded pressure vessels, boilers, air receivers.

**FINDLAY, ALEX., AND CO., LTD.**
Welded, riveted, construction; heavy, light.

**FIRTH BLAKELEY SONS AND CO., LTD.**
Gasholders, tanks, vessels, chimneys.

**FISHER AND LUDLOW, LTD.**
"Pisholow."

**FLEETLANDS, LTD.**
Welded to 10 tons; plastics.

**FLETCHER, C. W., AND SONS, LTD.**
Precision sheet metal workers, light engineers.

**FOSTER YATES AND THOM, LTD.**
Welded Class 1 pressure vessels; specials.

**FRASER, JOHN, AND SON, LTD.**
Vessels, riveted, welded, Class II; steel, clad.

**FREEMAN TAYLOR MACHINES, LTD.**
S.s.; pressure, chemical reaction vessels.

**FROST, H., AND CO., LTD.**
Pressings, assemblies, press tools.

**FOX CHEMICAL-ENGINEERING WORKS, LTD.**
Special machinery.

**FYFE, WILSON AND CO., LTD.**
Prototype machines, mechanisms.

**GARDNER, J., AND CO., LTD.**
Sheet metal, plate to ¼ in.

**GRAVINER MANUFACTURING CO., LTD.**
Special nuclear equipment.

**GRAZEBROOK, M. AND W., LTD.**
Steel, s.s., aluminium, pressure vessels.

**GRIFFITHS, A. E., (SMETHWICK), LTD.**
Reinforced plastics; sheet metal.

**GRIGG, CHARLES S. W., LTD.**
Heavy.

## 158 FABRICATIONS (contd.)

**GRINLAY, JAS., AND CO., LTD.**
Sheet metal.

**HALL BROTHERS (NETHERTON), LTD.**
M.s. 15 tons, plate rolling 1¾-in. thick.

**HALL ENGINEERING, LTD.**
Design; pressure vessels, tanks.

**HARGREAVES, HENRY, AND SONS, LTD.**
S.s.

**HARLAND AND WOLFF, LTD.**
General engineering, welding.

**HARVEY, G. A., AND CO. (LONDON), LTD.**
Heavy, sheet metal.

**HEAD WRIGHTSON AND CO., LTD.**
Vessels, tanks.

**HILLS (WEST BROMWICH), LTD.**
Steel.

**HOPKINS, G., AND SONS, LTD.**
S.s. plant.

**HORSELEY BRIDGE AND THOMAS PIGGOTT, LTD.**
Steel, s.s.; vessels, receivers, reactors.

**IDE, C. F., ENGINEERING, LTD.**
Steel.

**INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.**
Pressure vessels, tanks.

**IRVING ENGINEERING CO., LTD.**
Steel, s.s., aluminium, tanks, vessels; design.

**JEAVONS, E. E., AND CO., LTD.**
Welded; pipelines.

**JENKINS,, ROBERT, AND CO., LTD.**
Pressure, storage, vessels; m.s., s.s., clad; non-ferrous.

**JOHNSTONE, ARCHIBALD (ENGINEERS), LTD.**

**LEE (GUS) AND BOSWELL, LTD.**
Welding, rolling, guilloting, flanging, cutting; steel.

**LONDON ALUMINIUM COMPANY, LTD., THE.**
Aluminium, s.s.; welding; spinnings, pressings.

**LONGCLOSE ENGINEERING COMPANY, LTD.**
S.s.

**LONGFIELDS, LTD.**
All metals; s.s. specialists, nickel.

**LORD, R., AND SONS, LTD.**
General; vessels, m.s., clad, s.s.; welded, riveted.

**LOW, ARCHIBALD, AND SONS, LTD.**
Sheet metal work.

**LUCAS, JOSEPH, LTD.**
Welding, brazing; s.s. nimonics, titanium.

**LYONS, CLAUDE, LTD.**
Sheet metal work.

**MACLELLAN, P. AND W. (PULLIN), LTD.**
Vessels.

**MACHINE, MORTON, CO., LTD.**
Aluminium, m.s., s.s.; specials; designs.

**MAITLANDS (METAL WORKS), LTD.**
S.s. effluent tanks; vacuum pans; vessels.

**MARSH, H. S., LTD.**
Plate to 2 in.

**MARSTON EXCELSIOR, LTD.**
Light alloy.

**MASON, G. SAMUEL (CHEMICAL ENGINEERS), LTD.**
Chemical anti-corrosion plant; vessels (A).

**MATTERSON HUXLEN AND WATSON (SALES), LTD.**
Steel.

**METADUCTS, LTD.**
S.s.

**MICA AND MICANITE SUPPLIES, LTD.**
Mica products; laminated plastics.

**MILES DEVELOPMENT PRODUCTS, LTD.**
Design, manufacture; vacuum systems.

**MILLER, P. AND L., LTD.**
Design, developments; welding.

**MILLS, GEORGE (ENGINEERS), LTD.**
Steel.

**MILLSPAUGH, LTD.**
Vessels; foundry, welding, machining, heat treatment.

**MOORE, W. AND E., LTD.**
Tanks, platework.

**MOORES (BOURNEMOUTH), LTD.**
S.s., aluminium.

**MORTON, FRANCIS, AND CO., LTD.**
Platework, erection; heavy; light, sheet.

**MOTHERWELL BRIDGE AND ENGINEERING CO., LTD., THE.**
Designers, erectors; reactor pressure, containment vessels.

**NEILL, WM., AND SON (ST. HELENS), LTD.**
M.s., s.s., aluminium, to ½ in. thick.

**NOBRAC CARBON, LTD.**
Graphite.

**NORTH BRITISH LOCOMOTIVE CO., LTD.**
Pressure vessels.

**NORTH WEST MACHINE DESIGN CO., LTD.**
Design, draughting; machinery, mechanisms.

**ORTHOSTYLE, LTD.**
Platework; steel, chimney specialists.

**OXLEY ENGINEERING CO., LTD.**
Vessels, containers; m.s., s.s.

**PALATINE TOOL AND ENGINEERING CO. (SURBITON), LTD.**
Pressure vessels.

**PAYTER, E. C., AND CO., LTD.**
Aluminium alloy, structural welded plate.

**PEARSON, T. B., AND SONS, LTD.**
Vessels, lead lined; heavy plate; s.s.

**PHILLIPS AND BONSON, LTD.**
Sheet metalworking.

**PIPE FABRICATORS (STAMFORD), LTD.**
Rolled, welded platework.

**PIPEWELD, LTD.**
Tanks, vessels; tubular structures.

**PIPEWORK AND ENGINEERING (BRISTOL), LTD.**
General metal.

**PREMIER PRECISION, LTD.**
Research, development engineers, toolmakers.

**PULVERIZING MACHINERY, LTD.**
Pressure vessels, m.s., s.s., copper; glass lined.

**REDHEUGH IRON AND STEEL CO. (1936), LTD.**
Tanks, ducting, pipes.

**RESEARCH ENGINEERS, LTD.**
Experimental development engineers.

**REYNOLDS TUBE COMPANY, LTD.**
Steel, aluminium, alloy, s.s., nimonic, titanium.

**RHODES, GILL AND CO., LTD.**
M.s., s.s., monel metal pressure vessels.

**RHYMNEY ENGINEERING CO., LTD.**
Medium, heavy, structural; design facilities.

**RICHARDS AND ROSS, LTD.**
M.s., s.s., low alloy.

**RICHARDSONS, WESTGARTH AND CO., LTD.**
Pressure vessels.

**RICHARDSON, W., AND CO., LTD.**
Tanks.

**RILEY, ROBERT, LTD.**
Presswork; aluminium, brass, copper, s.s., m.s., steel.

**ROBERTSON AND FERGUSON, LTD.**
Steels; aluminium; to 10 tons.

**ROTINOFF GROUP.**
Steel.

**RUBERY, OWEN, AND CO., LTD.**
Steel; sheet metal.

**RUSTON AND HORNSBY, LTD.**
Specialized components, pressure vessels.

**RYDER, THOS., AND CO. (MANCHESTER), LTD.**
S.s., aluminium, copper, brass, steel, alloys.

**SAUNDERS-ROE (ANGLESEY), LTD.**
Steel, s.s., aluminium alloy, tanks, vessels, thimbles.

**SAVAGES, LTD.**
Steel prototype specialists.

**SCOTTS ENGINEERING (NEWPORT), LTD.**
Steel to 10 tons.

**SHERWOOD INSTRUMENTS, LTD.**
Sheet metal details.

**SHEEPBRIDGE EQUIPMENT, LTD.**
Steel, all types.

**SIMON-CARVES, LTD.**
Pressure vessels.

**SKINNINGROVE IRON CO., LTD.**
Steelwork, welded, riveted; rails, roof supports.

**SMITH, W. H., AND CO. (WHITCHURCH), LTD.**
Steel; riveted, welded, bolted to 10 tons.

**STAINLESS STEEL PROFILE CUTTERS, LTD.**
S.s.

**STEAM AND COMBUSTION ENGINEERING, LTD.**
Platework, vessels.

**STEPHEN, ALEX., AND SONS, LTD.**
Heavy steel boilers.

**STIRLING, R. B., AND CO., LTD.**
Light plate work to ¼-in. thick.

**STOCKTON CHEMICAL ENGINEERS AND RILEY BOILERS, LTD.**
M.s. vessels, Class II; presswork.

**STOCKDALE ENGINEERING, LTD.**
Acid-resisting plant, vessels, tanks, autoclaves.

**SAMUEL TALBOT (ENG'S), LTD.**
M.s., s.s. to 2 in., inconel, nimonic, etc.

**SOUTH DURHAM STEEL AND IRON CO., LTD.**
Steel tanks, pressure vessels.

**TANKS AND LININGS, LTD.**
Tanks, lined.

**THOMPSON BROS. (BILSTON), LTD.**
Reactor pressure vessels.

**THOMPSON, JOHN, LTD.**
Pressure vessels.

**TRANSFORMER AND ELECTRICAL CO., LTD., THE.**
Sheet metal.

**TUBEWRIGHTS, LTD.**
Tubular steelwork.

**TUPHOLME, GEORGE E., AND CO., LTD.**
General sheet metal.

**UNIVERSAL BOILERS AND ENGINEERING CO., LTD.**
Tanks, vessels, hoppers; steel to 20 tons.

**UNITED STATES METALLIC PACKING CO., LTD.**
Medium.

**UNIVERSAL METAL SPRAYERS, LTD.**
Welded.

**URQUHARTS (1926), LTD.**
Process plant.

**VERNON INSTRUMENTS CO., LTD.**
Design; manufacture (A).

**VICKERS-ARMSTRONGS (ENGINEERS), LTD.**
Shield plate assemblies, vessels, strip-wound specials.

**VICKERS NUCLEAR ENGINEERING, LTD.**
S.s. pressure vessels.

**VICTOR ELECTRICS, LTD.**

**VOKES, LTD.**
Approved Lloyd's Class II welders.

**WAKES AND LAMB.**

**WALKER, C. AND W., LTD.**
Tanks, vessels; c.i. steel.

**WATSON, ROBT., AND CO. (CONSTRUCTIONAL ENGINEERS), LTD.**
Welded steel platework, pressure vessels.

**WATTS METAL INDUSTRIES, LTD.**
Plate to ½ in.; sheet metal.

**WEBB, JOSEPH, AND SONS, LTD.**
Flame-cut plate to 10-in. thick.

**WELDALL AND ASSEMBLY, LTD.**
To 75 tons; vessels, chemical plant.

**WELDING TECHNICAL SERVICES, LTD.**
S.s., high nickel alloy; tanks, vessels.

**WESTERN DETAIL MANUFACTURERS, LTD.**
Precision engineering; design.

**WESTERN MANUFACTURING (READING), LTD.**
Prototype work, special-purpose rigs.

**WEST LONDON IRON AND WIRE WORKS, LTD.**
S.s.

**WEST'S GAS IMPROVEMENT CO., LTD.**
Welded steelwork.

**WESTWOOD, JOSEPH, AND CO., LTD.**
Riveted bridges, hoppers, tanks; sheet metal.

**WHESSOE, LTD.**
Reactor pressure vessels, containment vessels.

**WHITEHEAD, JOHN, ENG. (WILLSD.), LTD.**
Welded, to 2 tons; machining.

**WHITELEY-READ ENGINEERS, LTD.**
Vessels, receivers, tanks; welded platework.

**WIDNES WELDING CO.**
Tanks, etc.

**WILMOT BREEDEN, LTD.**
Sheet-metal pressure vessels.

**WILSON, EDWARD, AND SON, LTD.**
General engineering; special-purpose machinery.

**WINDSHIELDS OF WORCESTER, LTD.**
Light alloy, steel, pressure vessels, tanks.

**WINKWORTH MACHINERY, LTD.**
S.s.

**WOOD, EDWARD, AND CO., LTD.**

**WRIGHT ANDERSON AND CO., LTD.**
Plate; tanks, bunkers.

**WYKEHAM, W., AND CO., LTD.**
Reactor plant assemblies (A).

**YARROW AND CO., LTD.**
Ducting, pressure vessels.

**YORKSHIRE ENGINEERING AND WELDING CO. (BRADFORD), LTD.**
Aluminium, s.s.; tanks, lead lined.

## 159 FACTORY FITTINGS

**ACCESS EQUIPMENT, LTD.**
Aluminium staging, steps.

**AYRSHIRE DOCKYARD CO., LTD.**
Metal partitions.

**BETTLES AND SONS, LTD.**
Flooring, staircases, walkways; steel, aluminium.

**BOWES-SCOTT AND WESTERN, LTD.**
Treads, plates, tiles.

**BROADS MANUFACTURING CO., LTD.**
Pressure covers, gangways, ladders, hand railings.

**CARTER TILES, LTD.**
Glazed tiles.

**DEXION, LTD.**
Aluminium alloy, steel, slotted angle.

**EDENHALL CONCRETE PRODUCTS, LTD.**
Pre-cast floors, blocks, posts.

## 159 FACTORY FITTINGS (contd.)

**EXPANDED METAL CO., LTD., THE.**
Walkways, cable trays.

**FISHER AND LUDLOW, LTD.**
Steel, aluminium, flooring, shelving.

**GARDINER SONS AND CO., LTD.**
Ovalock flooring.

**HILLS (WEST BROMWICH), LTD.**
Glazing, glass walling.

**KENNEDY, ALLAN, AND CO., LTD.**
Flooring, treads; forged fabricated; standards, handrails.

**LIONWELD, LTD.**
Flooring, stairtreads, handrailing.

**RAPID METAL DEVELOPMENTS, LTD.**
Steel formwork, props, sheeting.

**RUBERY, OWEN AND CO., LTD.**
Partioning, storage, equipment, shelving.

**SANKEY-SHELDON, LTD.**
Unistrut steel framing; filing, shelving.

**TUPHOLME, GEORGE E. AND CO., LTD.**
Access ladders, platforms.

**UNIVERSAL ASBESTOS MANUFACTURING CO., LTD., THE.**
Asbestos cement roofing, cladding.

## 160 FILTERS

**AEROX, LTD.**
Ceramic; gas, liquid.

**AIR CONTROL INSTALLATIONS, LTD.**
Gas, air.

**AUTO-KLEAN STRAINERS, LTD.**
Oil, chemical, water.

**BIRMINGHAM PROTECTIVE CLOTHING CO., THE.**
Cloths; nylon, terylene to specification.

**BIVAC AIR CO., LTD.**
"Clear Flo" air.

**BOULTON, WILLIAM, LTD.**
Presses.

**BURNETT AND LEWIS, LTD.**
Air (adsorption).

**CALMIC ENGINEERING CO., LTD.**
Pressure.

**CARLSON, JOHN C., LTD.**
Filtration media.

**CHAMBERS FILTERBAG CO., LTD., THE.**
Bags.

**CROSBY VALVE AND ENGINEERING CO., LTD.**
Instruments, air regulator sets.

**DALLOW LAMBERT AND CO., LTD.**
"Drytube" dust.

**DAVEY, PAXMAN AND CO., LTD.**
Rotary vacuum, disc, pressure rotary.

**DOULTON INDUSTRIAL PORCELAINS, LTD.**
Gas, liquid; ceramic.

**FAIREY AVIATION CO., LTD., THE.**

**FIRKINS, G. AND A., LTD.**
Gas, liquid.

**HEAT TRANSFER, LTD.**
Gas, liquid.

**HEATHER FILTERS, LTD.**
Air.

**HOLMES, W. C., AND CO., LTD.**
Air, electronic.

**INTERMIT, LTD.**
Air, gases, oil; equipment.

**INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.**
Liquid.

**I.V. PRESSURE CONTROLLERS, LTD.**
Gas, liquid.

**JACKMAN, J. W., AND CO., LTD.**
Fabric screen; wet types.

**LUCAS, JOSEPH, LTD.**
Liquid.

**MANCUNA ENGINEERING, LTD.**

**METAL AND PLASTIC COMPONENTS CO., LTD.**
Porous, sintered; s.s., nickel, copper-nickel.

**METALFILTRATION CO., LTD.**
"Metafilters"; water purification to 20,000 g.p.h.

**MICA AND MICANITE SUPPLIES, LTD.**
"Miofiltre," air.

**MITCHELL, L. A., LTD.**
Filtration plants.

**NORGREN, C. A., LTD.**
Compressed air.

**OZONAIR ENGINEERING CO., LTD.**
Air; viscous; fabric, dry metal.

**PEABODY, LTD.**
Absorbers.

**PHILIPS ELECTRICAL, LTD.**
Magnetic.

**PREMIER COOLER AND ENGINEERING CO., LTD., THE.**
Air, "Adhesic" cloth pocket types.

**RICHARDSON, R. J., AND SONS, LTD.**
Agent.

**SHARPLES CENTRIFUGES, LTD.**
Clarifiers, oil purification equipment.

**SIMMONDS AEROCESSORIES, LTD.**
Liquid.

**SIMON-CARVES, LTD.**
Gas.

**SINTERED PRODUCTS, LTD.**
"Porosint" sintered metal.

**STILLITE PRODUCTS, LTD.**
"Stillite" pads.

**STOCKDALE ENGINEERING, LTD.**
Rotary vacuum, pressure, disc.

**STREAM-LINE FILTERS, LTD.**
Oil, water, air; specials.

**STURTEVANT ENGINEERING CO., LTD.**
Air; electrostatic, paper.

**THERMIX INDUSTRIES, LTD.**
Bags.

**THOMPSON-KENNICOTT, JOHN, LTD.**

**TOWNSON AND MERCER, LTD.**
Radio-active; pump unit.

**VERSIL, LTD.**
Glass fibre; replacement.

**VICKERYS, LTD.**
"Bird" centrifugal.

**VISCO ENGINEERING CO., LTD., THE.**
Air.

**VOKES, LTD.**
High efficiency equipment; quartz fibre, 1000°C.

**WALKER, P. M., AND CO. (HALIFAX), LTD.**
Air.

**WIDNES WELDING CO.**

## 161 FIRE PROTECTION

**FIRE ARMOUR, LTD.**
Extinguishers, engines, foam hydrant installations.

**FOAMITE, LTD.**
Engineers.

**HATHAWAY, L., LTD.**
Portable, general purpose pumps.

**KIDDE, WALTER, CO., LTD., THE.**
Extinguishers, alarms, ancillary equipment.

**MERRYWEATHER AND SONS, LTD.**
Alarms, extinguishers, pumps.

**MINERVA DETECTOR CO., LTD., THE.**
Nuclear system, control units, signal panels.

**NU-SWIFT, LTD.**
Hand extinguishers.

**PILLINGER, G. C., AND CO., LTD.**
Automatic water distribution systems.

**PYRENE CO., LTD., THE.**
Hand extinguishers: installations; detecting, alarms.

**THERMAL CONTROL CO., LTD.**
Fire detection systems.

**TURNERS ASBESTOS CEMENT CO., LTD.**
Board, sprayed.

## 162 FLAW DETECTION
*see also RADIOGRAPHY*

**AIRMEC, LTD.**
Ultrasonic.

**BRAMAH, J. R., AND CO., LTD.**
Magnetic.

**BRITISH THOMSON-HOUSTON CO., LTD., THE.**
Leak detectors.

**CAWKELL RESEARCH AND ELECTRONICS, LTD.**

**C.N.S. INSTRUMENTS, LTD.**
Ultrasonic; bonding, graphite; eddy current.

**FALK, M., AND CO., LTD.**
Ultrasonic; magnetic detectors; consultancy service.

**GLASS DEVELOPMENTS, LTD.**
Ultrasonic.

**GRUBB, SIR HOWARD, PARSONS AND CO., LTD.**
Gas leak detectors.

**INDUSTRIAL RADIOGRAPHY (NDT), LTD.**
Ultrasonic, vacuum leak; on site.

**INFRA RED DEVELOPMENT CO., LTD.**
Leak measuring.

**KELVIN AND HUGHES (INDUSTRIAL), LTD.**
Ultrasonic.

**METAL AND PIPELINE ENDURANCE, LTD.**
Weld inspection, leak detection services.

**SOLUS-SCHALL, LTD.**
Ultrasonic, magnetic, eddy current; consultants; service.

**SPERRY GYROSCOPE CO., LTD.**
Eddy current.

**TELEDICTOR, LTD.**
Crack detectors.

**ULTRASONOSCOPE CO. (LONDON), LTD.**
Ultrasonic; automated inspection.

**UNIT SUPERHEATER AND PIPE CO., LTD THE.**
Ultrasonic, gas leak testing.

**WELDING SUPPLIES, LTD.**
Magnetic.

**WELDING SUPERVISION, LTD.**
Shop, site service.

**WILFLO PRODUCTS, LTD.**
Magnetic crack detectors.

## 163 FORGINGS

**ADAMSON, JOSEPH, AND CO., LTD.**
Pressings; heads, reactor boilers, pressure vessels.

**ALMIN, LTD.**
Aluminium.

**BAYLISS, JONES AND BAYLISS, LTD.**
Upset hammer.

**BEARDMORE, WILLIAM, AND CO., LTD.**

**BEARDSHAW, J., AND SON, LTD.**
Hot-rolled alloy, carbon steel; bars.

**BIRFIELD INDUSTRIES, LTD.**
Drop.

**BURTON, DELINGPOLE AND CO., LTD.**
Steel ring nozzle flanges; specials, 6 ft.

**CARY, WILLIAM E., LTD.**
To 5 cwt.

**CRITTALL-LUXFER, LTD.**
Aluminium, magnesium; non-ferrous, steel; extrusions.

**DENNYSTOWN FORGE CO., LTD., THE.**
Steel.

**ENGLISH STEEL FORGE AND ENGINEERING, CORP., LTD.**
Steel; rolled plate 1¼ in. to 16 in.

**FIRTH, THOS., AND JOHN BROWN, LTD.**
Collars, gearing, rolled rings.

**FIRTH, THOS., AND JOHN BROWN, LTD.**
Turbine, generator, shafting.

**FIRTH-DERIHON STAMPINGS, LTD., THE.**
S.s., heat, creep-resisting; nimonic, titanium alloys.

**GRAZEBROOK, M. AND W., LTD.**
Hot pressings.

**GUEST INDUSTRIALS, LTD.**
Heavy steel; agents for S.I.A.C.

**HADFIELDS, LTD.**
Steel.

**HIGH DUTY ALLOYS, LTD.**
Aluminium, magnesium alloys.

**HINGLEY, N., AND SONS (NETHERTON), LTD.**
Rolled rings, steel, light alloys, titanium.

**JESSOP, WM., AND SONS, LTD.**
Constructional; s.s.

**KIRK AND CO. (TUBES), LTD.**
Drop.

**LANGLEY ALLOYS, LTD.**
S.s., nickel alloy.

**LIGHT-METAL FORGINGS, LTD.**
Precision; m.s. alloy, Magnox, aluminium, zirconium alloys.

**MILLS, GEORGE, (ENGINEERS), LTD.**
Steel to 3 cwt.

**MOSS AND GAMBLE BROS., LTD.**
Steel; solid steel blocks.

**MOUNTFORD, JOHN, AND CO., LTD.**
Alloy, carbon steel.

**OXLEY, WM., AND CO., LTD.**
S.s.

**REYNOLDS TUBE COMPANY, LTD.**
Hollow steel; aluminium alloy.

**SAVILLE, J. J., AND CO., LTD.**

**SMITH, W. H., AND CO. (WHITCHURCH), LTD.**
Smithwork.

**SOMERS, WALTER, LTD.**
Alloy, carbon steel.

**STEEL, PEECH AND TOZER.**
Forged, rolled, steel, rings, bars.

**TALBOT STEAD TUBE CO., LTD.**
Bright turned, polished shafting.

**WEBB, JOSEPH, AND SONS, LTD.**
Carbon, alloy steels; machined; to 10 tons.

## 164 FUEL ELEMENTS

**ACCLES AND POLLOCK, LTD.**
Cans; magnox, niobium, vanadium, s.s.

**BABCOCK AND WILCOX, LTD.**
Handling equipment.

**CRITTALL-LUXFER, LTD.**
Cans.

**DE HAVILLAND ENGINE CO., LTD., THE.**
Loop testing equipment.

**ELECTRO-HYDRAULICS, LTD.**
Handling equipment, machine tools.

**EVANS, J., AND SON (PORTSMOUTH), LTD.**
Decanning; cooling pond equipment.

**FAIREY AVIATION CO., LTD., THE.**
Cans; handling; coffins, grabs, pond equipment.

**FLETCHER, C. W., AND SONS, LTD.**
Casings.

**HEAD WRIGHTSON PROCESSES, LTD.**
Handling equipment.

**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
Can fabrication.

**INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.**
Handling; flasks, winches, coffins.

**IRWIN, E. G. AND PARTNERS, LTD.**
De-canning, sectioning machines; transport flasks.

**NEWBURGH ENGINEERING CO., LTD.**
Cans, components, struts.

**SCREW MACHINE PRODUCTS, LTD.**
Components.

**STRACHAN AND HENSHAW, LTD.**
Handling equipment.

**T.I. NUCLEAR ENGINEERING, LTD.**
Sheaths; magnesium, aluminium, zirconium, niobium, vanadium, beryllium; s.s. supports.

**VICKERS-ARMSTRONGS (ENGINEERS), LTD.**
Decanning machinery.

**WILSON, A. C., AND PARTNERS, LTD.**
Remote controlled machine tools.

**WILSON, EDWARD, AND SON, LTD.**
Handling.

## 165 FUME TREATMENT

**BRAMAH, J. R., AND CO., LTD.**
Hoods.

**CHEMICAL ENGINEERING CONSTRUCTION (PENSNETT), LTD.**

**GRIFFITHS, A. E., (SMETHWICK), LTD.**
Tanks, chemicals, fume extraction.

**HALL AND KAY, LTD.**
Fume extraction.

**LAMSON ENGINEERING CO., LTD.**
Fume, dust extraction.

**MIDLAND HEATING AND VENTILATION CO., LTD.**

**PEABODY, LTD.**
Dust, fume, mist removal.

**POWER-GAS CORPORATION, LTD., THE.**
Gas cleaning.

**PRODORITE, LTD.**
Corrosive fume extraction schemes.

**SPENCER AND HALSTEAD, LTD.**
Removal plant.

**SUPERVENTS, LTD.**
Fume, vapour, exhaust systems; drying plant.

## 166 FURNACES

**A.E.W., LTD.,**
Electric.

**BARLOW-WHITNEY, LTD.**
Electric.

**BAYLEY, F. S., CLANAHAN AND CO., LTD.**
"Degussa."

**BRISTOL AERO-ENGINES, LTD.**
In-pile.

**CATTERSON-SMITH, R. M., LTD.**
Electric resistance; 450°C to 1,750°C; special.

**DELAPENA AND SON, LTD.**
Vacuum melting, sintering; associated equipment.

**EFCO-EDWARDS VACUUM METALLURGY, LTD.**
Vacuum melting, casting, degassing, sintering, brazing.

**ELECTRIC RESISTANCE FURNACE CO., LTD.**
Sintering, vacuum, stress relieving.

**FLEISCHMANN (LONDON), LTD.**
High vacuum.

**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
Heat treatment.

**JOHNSON, MATTHEY AND CO., LTD.**
Crucible, muffle, tube.

**KEPSTON, LTD.**
High temperature; heat treatment facilities.

**LEYBOLD VACUUM SALES, LTD.**
Uranium; vacuum (A).

**MELDRUM FLOOD-PAGE, LTD.**
Forced draught.

**ROYCE ELECTRIC FURNACES, LTD.**
Ovens; laboratory; industrial.

**SINTERING AND BLAZING FURNACES, LTD.**
Electric high temperature.

**STABILAG CO., LTD.**
Tunnel ovens.

**STEIN AND ATKINSON, LTD.**
Oil, gas, electric; stress-relieving; treatment.

**VACUUM INDUSTRIAL APPLICATIONS, LTD.**
Vacuum sintering, melting.

**V.M.D., LTD.**
Vacuum; metallising, casting, brazing, sintering.

**WALKER, C. AND W., LTD.**
Vacuum ovens.

**WILD-BARFIELD ELECTRIC FURNACES, LTD.**
Vacuum; induction, arc, resistance heated.

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## 167 GAS ANALYSIS

**CAMBRIDGE INSTRUMENT CO., LTD.**

**COMBUSTION INSTRUMENTS.**
CO test.

**EFCO-EDWARDS VACUUM METALLURGY, LTD.**
Hydrogen content.

**ENGELHARD INDUSTRIES, LTD.**
Oxygen indicators.

**GRUBB, SIR HOWARD, PARSONS AND CO., LTD.**
$CO_2$/steam, steam/$CO_2$ monitors.

**INFRA RED DEVELOPMENT CO., LTD.**
CO, $CO_2$, water vapour.

**INTERNATIONAL GAS DETECTORS, LTD.**
Gas, hydrogen, $CO_2$ alarms.

**K.G.M. ELECTRONICS, LTD.**
Fluorimeters.

**MERVYN INSTRUMENTS.**
Spectrometers, square wave polarograph, sulphur dioxide recorder; proportiometer, mercury electrode.

**WILD-BARFIELD ELECTRIC FURNACES, LTD.**
Vacuum.

## 168 GAUGES

*see also INSTRUMENTS, PROCESS CONTROL*

**APPLEBY AND IRELAND, LTD.**
Direct, remote, pressure, vacuum.

**BAYHAM, LTD.**
Contents, level, flow.

**BRITISH ROTOTHERM CO., LTD., THE.**
Pressure, temperature.

**BUDENBERG GAUGE CO., LTD.**
Pressure.

**EDWARDS HIGH VACUUM, LTD.**
Vacuum accessories.

**FARNELL INSTRUMENTS, LTD.**
High temperature strain.

**FOSTER INSTRUMENT CO., LTD.**
Temperature.

**GLASS DEVELOPMENTS, LTD.**
Atmospheric pollution, micro-manometers.

**HONEYWELL CONTROLS, LTD.**
Flow, pressure, temperature.

**LINTRONIC, LTD.**
Pressure.

**N.G.N. ELECTRICAL, LTD.**
Demountable pirani, discharge tube.

**PAYNE AND GRIFFITHS, LTD.**
Pressure, vacuum.

**RHODES, B., AND SON, LTD.**
Sight flow.

**SUPERHEATER CO., LTD., THE.**

**SMITH, SYDNEY, AND SONS (NOTTINGHAM), LTD.**
Level, pressure, vacuum.

**VACUUM RESEARCH (CAMBRIDGE), LTD.**
Pirani, cold cathode, ion, water flow.

## 169 GEARS

**ALLEN, W. H., SONS AND CO., LTD.**
Epicyclic, boiler feed pump drive.

**ALLSPEEDS, LTD.**
"Kopp" variator; infinitely variable speed.

**ASSOCIATED ELECTRICAL INDUSTRIES, LTD.**
Precision.

**BOSTOCK AND BRAMLEY, LTD.**
Gearing.

**DAVID BROWN CORPORATION (SALES), LTD., THE.**
"Radicon," spiral bevel, helical units.

**DAVID BROWN INDUSTRIES, LTD.**

**BROWN, S. G., LTD.**
Precision gear trains.

**CARTER GEARS, LTD.**
Variable speed.

**CENTRAX, LTD.**
Precision; gearboxes.

**CRAVEN BROTHERS (MANCHESTER), LTD.**
Cutting to 27 ft dia.

**CROFTS (ENGINEERS), LTD.**

**DEVON INSTRUMENTS, LTD.**
Miniature boxes.

**ELECTROPOWER GEARS, LTD.**
Geared motors, gearboxes.

**GLASS DEVELOPMENTS, LTD.**
Cutting, spiral, bevel.

**HIGHFIELD GEAR AND ENGINEERING CO., LTD.**
Spur, helical, spiral, bevel worm; units.

**HOLROYD, J., AND CO., LTD.**
Worm; speed reducers.

**HORSTMANN GEAR CO., LTD., THE.**
Precision.

**McKELLAN, S. D., LTD.**
Assemblies.

**MATTERSON, LTD.**
Change speed, infinitely variable boxes.

**MERCER, THOMAS, LTD.**

**MODERN WHEEL DRIVE, LTD.**
Boxes.

**NORTHERN MANUFACTURING CO., LTD., THE.**
Spur to 12 ft, bevel 3 ft, worm 6 ft 6 in.

**RELIANCE GEAR AND ENGINEERING CO. (SALFORD), LTD.**

**SHEEPBRIDGE EQUIPMENT, LTD.**
Cutting.

**TURBINE GEARS, LTD.**
All types and sizes.

**VARATIO STRATELINE GEARS, LTD.**
"Stratelinе speed reducers," "Varatio" positive V.S.

**WESTERN MANUFACTURING (READING), LTD.**
Cutting.

**WEYERS BROS., LTD.**

**WISEMAN, ALFRED, AND CO., LTD.**
Cutting; boxes; reduction, increasing, units; motor.

## 170 GENERATORS

**ALLEN, W. H., SONS AND CO., LTD.**
A.C. to 2,000 kW, d.c. 3,000 kW.

**BROTHERHOOD, PETER, LTD.**

**B.V.C. ELECTRONIC DEVELOPMENTS, LTD.**

**C.A.V., LTD.**
Low voltage.

**CROMPTON PARKINSON, LTD.**
D.C. alternators to 1,500 kVA.

**CROYDON ENGINEERING CO., LTD., THE.**
Alternators.

**ELECTRICAL POWER ENGINEERING CO. (B'HAM), LTD., THE.**
Flameproof.

**ELECTRO DYNAMIC CONSTRUCTION CO., LTD.**
Alternators.

**HARLAND AND WOLFF, LTD.**
A.C., d.c.

**HIGGS MOTORS, LTD.**

**LAURENCE, SCOTT AND ELECTROMOTORS, LTD.**
High-performance; associated voltage control.

**LUCAS, JOSEPH, LTD.**

**LYON, ARTHUR, AND CO. (ENGINEERS), LTD.**
"Stamford" standard, newphase, E.S. alternators.

**MATHER AND PLATT, LTD.**

**NELSON ENGINEERING CO., LTD., THE.**

**NEWTON BROS. (DERBY), LTD.**
Motor.

**PARSONS, C. A., AND COMPANY, LTD.**

**RICHARDSONS, WESTGARTH AND CO., LTD.**
Alternators to 275 MW.

**SMALL ELECTRIC MOTORS, LTD.**
D.C. alternators.

## 171 GLASSWARE

CAMLAB (GLASS), LTD.
IDE, T. AND W., LTD.
Dials, bezels, graduated scales, etc.
JENCONS (SCIENTIFIC), LTD.
Specialists; graded seals; quartz; cones, sockets.
JOBLING, JAMES A., AND CO., LTD.
Pyrex scientific, industrial.
PLOWDEN, M., AND THOMPSON, LTD.
Tubing, rod; phoenix borosilicate tubing (A).
Q. V. F., LTD.
"Quickfit."
RESEARCH UTILITIES, LTD.
Precision laboratory apparatus.

## 172 G-M TUBES

GENERAL ELECTRIC CO., LTD.
MULLARD, LTD.
RESEARCH AND CONTROL INSTRUMENTS, LTD.
Tubes, halogen quenched.
20TH CENTURY ELECTRONICS, LTD.
Complete range.

## 173 GRAPHITE

ACHESON COLLOIDS, LTD.
"Dag" dispersions.
BRITISH ACHESON ELECTRODES, LTD.
"Acheson"; "Korbate" impervious graphite.
BRITISH JEFFREY-DIAMOND, LTD.
Crushers.
BROOKE TOOL MFG. CO., LTD., THE.
Unit heads, machines for machining.
ENGLISH ELECTRIC CO., LTD., THE.
Machined.
FAIREY AVIATION CO., LTD., THE.
Thermal columns; Wigner growth micrometers.
GRAVINER MANUFACTURING COMPANY, LTD.
Machining; reactor reflectors.
HALL, MATTHEW, AND CO., LTD.
Laying; support features.
HAWKER SIDDELEY NUCLEAR POWER CO., LTD.
Impermeable.
MORGAN CRUCIBLE CO., LTD., THE.
NEW METALS AND CHEMICALS, LTD.
Reactor grade.
NOBRAC CARBON, LTD.
Heaters, anodes, crucibles, seals, bearings, fabrications.
NUCLEAR GRAPHITE, LTD.
Block machining.
POWELL DUFFRYN CARBON PRODUCTS, LTD.
Manufacturers; nuclear machinists; carbon, chemical equipment.
WADKIN, LTD.
Machining.
WARD, THOS. W., LTD.
Laying.

# H

## 174 HEALTH MONITORS

AVO, LTD.
Hot-spot monitors.
BALDWIN INSTRUMENTS CO., LTD.
X-ray dosemeters.
B.M.B. (SALES), LTD.
Personnel cleaner.
BURNDEPT, LTD.
Alpha, beta/gamma, neutron.
CINEMA-TELEVISION, LTD.
Portable alpha, beta, gamma; pocket.
EKCO ELECTRONICS, LTD.
Alpha, beta, gamma, neutron; ionisation chambers.
ELLIOTT NUCLEONICS, LTD.
ERICSSON TELEPHONES, LTD.
General purpose; portable.
FLEMING RADIO (DEVELOPMENTS), LTD.
Air pollution recorder, effluent monitor.
GENERAL RADIOLOGICAL, LTD.
KODAK, LTD.,
Films.
MULLARD EQUIPMENT, LTD.
Hand and clothing.
NASH AND THOMPSON, LTD.
Portable dust monitor.
NUCLEAR ENTERPRISES (G.B.), LTD.
Body counting installations.
PANAX EQUIPMENT, LTD.
Portable, mains.
PLESSEY NUCLEONICS, LTD.
Installed, portable.
RANK CINTEL, LTD.
"C.K." dosimeters.
RESEARCH AND CONTROL INSTRUMENTS, LTD.
Contamination meters, dosemeters.
SAVAGE AND PARSONS LTD.
Film holders.
STEPHEN, R. A., AND CO., LTD.
Quartz fibre dosemeters.
TOWERS, J. W., AND CO., LTD.

## 175 HEATERS

*see also INDUCTION HEATING*

BACKER ELECTRIC CO., LTD.
Immersion, infra red, pipe tracing, bolt heating.
BADDELEY, D. S., ENG. CO., LTD.
Acetylene.
BARLOW-WHITNEY, LTD.
Gas flow.
BARTER AND SONS, LTD.
Gas burners.
BRAY, GEO., AND CO., LTD.
Strip, ring, tubular elements; gas, spray jets.
BRITISH DRIVER-HARRIS CO., LTD.
Resistance wires, strips.
ELECTROTHERMAL ENGINEERING, LTD.
Surface, electric; plant.
ELECTROWAY HEATERS, LTD.
Air batteries; reactor; muff, process, electric.
ELTRON (LONDON), LTD.
Elements, resistances.
EXPANDED METAL CO., LTD., THE.
ISOPAD, LTD.
Electric surface; heating mantles.
PRINTED CIRCUITS, LTD.
RADIO HEATERS, LTD.
R F induction, dielectric, sheet.
REDIFON, LTD.
R F induction; dielectric.
ROYCE ELECTRIC FURNACES, LTD.
Units, elements.
SALTER, T. E., LTD.
Air, to 500°F.
SPIRAL TUBE AND COMPONENTS CO., LTD., THE.
Air unit; heat transmission engineers.
STABILAG CO., LTD.
Immersion, jackets, infra-red, tapes.
STANDARD AND POCHIN BROS., LTD., THE.
Air, unit, convector.
SUPERHEATER CO., LTD., THE.
Air.
TETRA ENG. CO., LTD.
Elements.
THERMO ENGINEERS, LTD.
Air.
UNITY HEATING, LTD.
Electric, wide range.
URQUHARTS (1926), LTD.
Liquid fuel fired, co-axial, air.
VACTITE WIRE CO., LTD.
Resistance wires, tapes.
WALKER, C. AND W., LTD.
Pipe.
WALKER, P. M., AND CO. (HALIFAX), LTD.
Units.
WELLINGTON TUBE WORKS, LTD.
Panels.
ZEPHAIR, LTD.
Industrial air.

## 176 HEAT EXCHANGERS

ADAMSON, DANIEL, AND CO., LTD.
Tubular.
ALLEN, ALFRED, AND SON, LTD.
Casings.
ASHMORE, BENSON, PEASE AND CO.
Gas/gas, gas/water.
BABCOCK AND WILCOX, LTD.
B. A. P. (WELDING ACCESSORIES DIV.), LTD.
BALFOUR, HENRY, AND CO., LTD.
BIRWELCO, LTD.
Gas/gas, gas/water.
BRITISH ACHESON ELECTRODES, LTD.
BRITISH BOILER ACCESSORIES, LTD.
"Helitube."
BROWN, JOHN, AND CO., LTD.
Gas/gas, gas/water.
CASTON BARBER AND CO., LTD.
CLARKE, CHAPMAN AND CO., LTD.
Gas/gas, gas/water.
COCHRAN AND CO., ANNAN, LTD.
COVENTRY RADIATOR AND PRESSWORK CO., LTD.
CUPROCYL, LTD.
Calorifiers.
DAVEY, PAXMAN AND CO., LTD.
Gas/gas, gas/water.
DELANEY GALLAY, LTD.
Design, production.
DEWRANCE AND CO., LTD.
ELECTRO-HYDRAULICS, LTD.
EMPYRIUM WELDING—MANUFACTURING CO., LTD.
Condensers, evaporators.
FAIREY AVIATION CO., LTD., THE.
FREEMAN TAYLOR MACHINES, LTD.
HEAD WRIGHTSON AND CO., LTD.
HEAD WRIGHTSON PROCESSES, LTD.
Tubular, air-cooled.
HEAT EXCHANGERS, LTD.
Gas/gas, gas/water, metal/metal, metal/water.
HEAT TRANSFER, LTD.
Gas/gas, gas/water, metal/metal, metal/water.
IMPERIAL CHEMICAL INDUSTRIES, LTD.
Fluids.
INTERNATIONAL COMBUSTION (NUCLEAR APPLIANCES), LTD.
KLEEN-E-ZE BRUSH CO., LTD., THE.
Gilling-coils; flow-breakers, turbulators.
LUCAS, JOSEPH, LTD.
Gas/gas, gas/liquid.
MARSTON EXCELSIOR, LTD.
Non-ferrous.
MILLS PAUGH, LTD.
NEILL, WM., AND SON (ST. HELENS), LTD.
PEARSON, T. B., AND SONS, LTD.
Gas/gas.
PIPEWELD, LTD.
PREMIER COOLER AND ENGINEERING CO., LTD., THE.
Tubular.
RATZER, JOHN H., LTD.
RICHARDS AND ROSS, LTD.
Coils, assemblies.
RYDER, THOS., AND CO. (MANCHESTER), LTD.
SERCK RADIATORS, LTD.
Primary, secondary surface.
SPIRAL TUBE AND COMPONENTS CO., LTD., THE.
STEAM AND COMBUSTION ENGINEERING, LTD.
STEPHEN, ALEX, AND SONS, LTD.
SHORROCK SUPERCHARGERS, LTD.
Superchargers, I.C. engines.
SIMON-CARVES, LTD.
SPIRO-GILLS, LTD.
Gas/gas, gas/water.
STEEL, J. M., AND CO., LTD.
"Diphyl" heat transfer medium.
SUPERHEATER CO., LTD., THE.
Shop fabricated; unit.
THERMO ENGINEERS, LTD.
THOMPSON BROS. (BILSTON), LTD.
THOMPSON, JOHN, LTD.
UNIVERSAL METALLIC PACKING CO., LTD., THE.
Tubular.
URQUHARTS (1926), LTD.
UNITED AIR COIL, LTD.
Gas/gas, gas/water, metal/metal.
VICKERS NUCLEAR ENGINEERING, LTD.
All types.
WALKER, C. AND W., LTD.
WEATHERFOIL HEATING SYSTEMS, LTD.
Transfer equipment.
WELLINGTON TUBE WORKS, LTD.
Plain tube, extended surface, air cooled.
WILMOT BREEDEN, LTD.
WORTHINGTON-SIMPSON, LTD.
YORKSHIRE ENGINEERING AND WELDING CO. (BRADFORD), LTD.
Gas/gas.

## 177 HEAVY WATER

BROWN, JOHN, AND CO., LTD.
Production plant.
EKCO ELECTRONICS, LTD.
Leak indicator.
ENGELHARD INDUSTRIES, LTD.
Exchange catalysts.

## 178 HYDRAULIC PLANT

ANDERSTON CLYDE ENGINEERS, LTD.
Access equipment.
ARMSTRONG PATENTS CO., LTD.
Actuators.
ARROL, SIR WILLIAM, AND CO., LTD.
AUTOMOTIVE PRODUCTS COMPANY, LTD.
Complete systems; valves, pumps, motors, etc.
BARRUS, E. P., (CONCESSIONAIRES), LTD.
BRYCE BERGER, LTD.
Starters, fuel injection.
CHAMBERLAIN INDUSTRIES, LTD.
Motors, pumps, rams.
EPCO, LTD.
Pumps, rams.
FRASER, ANDREW, AND CO., LTD.
Motors, control gear.
GARDNER, J. STARKIE, LTD.
Development engineers.
GOODWIN, ARNOLD, LTD.
Cylinders, rams, pumps, valves.
HAMWORTHY ENGINEERING, LTD.
Pumps, valves.
IBBETT ENGINEERING CO., LTD.
"Eezion" ground level, on/off.
INTEGRAL, LTD.
Pumps, motors, power packs.
KEELAVITE HYDRAULICS, LTD.
Power control, transmission; design, installation.
LANGDALE ENGINEERING CO.
Infinitely variable, high pressure pumps, valves.
LUCAS, JOSEPH, LTD.
Equipment, motors, pumps, valves, meters.
McTAGGART SCOTT AND CO., LTD.
Pumps, motors, transmission sets.
MADAN, CHARLES S., AND CO., LTD.
Pumps, intensifiers valves, high pressure.
MARTONAIR, LTD.
Equipment, control valves.
MUIRHEAD AND CO., LTD.
Relays.
NORTH BRITISH LOCOMOTIVE CO., LTD.
Torque convertors.
POWER JACKS, LTD.
Jacks.
RHODES, GILL AND CO., LTD.
Cylinders, rams.
SPENBRAUGH ENGINEERING CO., LTD.
Ram assemblies, pumps, control valves.
STEIN ATKINSON VICKERS HYDRAULICS, LTD.
Power transmission equipment.
STEVEN, A. AND P., LTD.
Presses, pumps.
TANGYES, LTD.
Cylinders, rams, presses, machines.
TEDDINGTON INDUSTRIAL EQUIPMENT, LTD.
High temperature pumps, rams.
TEST EQUIPMENT, LTD.
Actuators.
THERMOCONTROL INSTALLATIONS CO., LTD.
Actuators.
TOWLER BROS. (PATENTS), LTD.
High pressure pumps.
TUBELA ENGINEERING CO., LTD.
High pressure pumps, rams.
UNITED STATES METALLIC PACKING CO., LTD.
Power cylinders.
WELDALL AND ASSEMBLY, LTD.
Presses, design service.
WILD, THOS. C., (MACHINERY), LTD.

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## 179 IMPREGNATING PLANT, VACUUM

BARLOW-WHITNEY, LTD.
EDWARDS HIGH VACUUM, LTD.
VACUUM INDUSTRIAL APPLICATIONS, LTD.

## 180 INDUCTION HEATING

DELAPENA AND SON, LTD.
HYGROTHERM ENGINEERING, LTD.
Mains frequency.
ISOPAD, LTD.
Mains frequency.
RADIO HEATERS, LTD.
REDIFON, LTD.
WILD-BARFIELD ELECTRIC FURNACES, LTD.

## 181 INSTALLATIONS, ELECTRICAL

ACTON, G.
BAILEY, N. G., AND CO., LTD.
Thermocouples and control specialists.
BRITISH CENTRAL ELECTRICAL CO., LTD.
BROXLEA PRODUCTS, LTD.
Wiring, cable forming, relay adjusting.
CABLE JOINTERS, LTD.
DRAKE AND GORHAM (CONTRACTORS), LTD.
Design, maintenance.

## 182 INSTRUMENTATION, NUCLEAR REACTOR

BROWN, JOHN, AND CO., LTD.
DOWTY NUCLEONICS, LTD.
Flux-scanning; B.F.E.D.
DUTHIE, R. HUTCHEON, AND SON, LTD.
Installation.
EKCO ELECTRONICS, LTD.
Complete; flux, power; monitors.
ELLIOTT NUCLEONICS, LTD.
Complete.
ERICSSON TELEPHONES, LTD.
Complete systems, interlock units, safety circuits.
FAIREY AVIATION CO., LTD., THE.
Shut-down; flux scanning, ion chambers, interlocks.
GENERAL RADIOLOGICAL, LTD.
Flux measuring, period meters, shut-down amplifiers.
GRUBB, SIR HOWARD, PARSONS AND CO., LTD.
Flux scanning.
HALL, MATTHEW, AND CO., LTD.
Installation; burst fuel element detection.
HEAT TRANSFER, LTD.
INTEGRA, LEEDS AND NORTHRUP, LTD.
ISOTOPE DEVELOPMENTS, LTD.
D.C., shut-down amplifiers.
KENT, GEORGE, LTD.
Position indicators.
KETAY, LTD.
Rod position indicators.
MARCONI INSTRUMENTS, LTD.
Systems engineering.
METROPOLITAN-VICKERS ELECTRICAL CO., LTD.
MULLARD EQUIPMENT, LTD.
Transistorized safety systems, sequence control.
PLESSEY NUCLEONICS, LTD.
Complete reactor control.
SALFORD ELECTRICAL INSTRUMENTS, LTD.
SIGMA INSTRUMENT CO., LTD.
Special purpose components.
SPERRY GYROSCOPE CO., LTD.
Rod position indicators; control systems.
SUNVIC CONTROLS, LTD.
B.F.E.D., data-processing systems.
THOMPSON, JOHN, LTD.

## 183 INSTRUMENTS, PROCESS CONTROL

*see also GAUGES*

A.C.M. ELECTRONICS.
Stabilised supplies, timers, development, design.
A.E.W., LTD.
Pyrometers.
AIRFLOW DEVELOPMENTS, LTD.
Orifice plates, gas flow, manometers, filter.
AIRMEC, LTD.
ALEXANDER CONTROLS, LTD.
Pressure switches.
ALTO INSTRUMENTS (GREAT BRITAIN), LTD.
Flow, concentration.
ATKINS, ROBERTSON AND WHITEFORD, LTD.
Electronic prototypes, batching counters, timers.
AVO, LTD.
Photo transistor relay meter.
BAILEY METERS AND CONTROLS, LTD.
Flow, pressure, temperature, differential transmission equipment.
BAILEY, SIR W. H., AND CO., LTD.
Flow, pressure, regulators.
BARNET INSTRUMENTS, LTD.
Pressure, vacuum, hydraulic gauges; pressure testing.
BAYLEY, F. S., CLANAHAN AND CO., LTD.
"Degussa" pyrometer equipment.
BENNETT, L. M., AND CO.
Automatic control consultants.
BOULTON PAUL AIRCRAFT, LTD.
Precision manometers, strain gauges; design capacity.
BRITISH ARCA REGULATORS, LTD.
Temperature, pressure, humidity, level, consistency.
BRITISH PITOMETER CO., LTD.
Pitot tubes, recorders; venturi, orifice; flow, level.
BURRELL, A. G., AND CO., LTD.
Process timers, cycle controllers.
CAMBRIDGE INSTRUMENT CO., LTD.
Temperature, pH, pressure.
CARTER, B. AND F., AND CO., LTD.
"Albion" precision counting.
CASS AND PHILLIP, LTD.
Elapsed time.
CLAYTON ENGINEERING CO.
Precision rotation indicators.
CLEVELAND METERS, LTD.
Integrating, indicating, flow; water, oil, gas.
C.N.S. INSTRUMENTS, LTD.
Temperature controllers, thermometers, tachometers, hygrometers.
COMBUSTION INSTRUMENTS.
Manometers, CO-test.
DANFOSS MANUFACTURING CO.
Thermostats, pressure switches.
DARTON, F., AND CO., LTD.
Barometers, manometers, hygrometers, thermographs, hygrographs.
DEVON INSTRUMENTS, LTD.
Timers.
DOWTY NUCLEONICS, LTD.
High-grade electro-mechanical indicators.
DRAYTON REGULATOR AND INSTRUMENT CO., LTD.
Temperature, pressure; controllers.
EPCO-EDWARDS VACUUM METALLURGY LTD.
Vacuum.
ELCONTROL, LTD.
Timers; level, flame monitoring, photoelectric relays, specials.
ELECTRICAL REMOTE CONTROL CO., LTD.
Automatic timing, multiple contact mercury relays.
ELECTRICALS, LTD.
Agent.
ELECTROFLO METERS CO., LTD.
Flow, level, pressure, temperature.
ELECTRONIC MACHINE CO., LTD.
Counters, timers, specials.
ELECTRONIC SWITCHGEAR (LONDON), LTD.
Conductivity bridges, recorders; fluid level.
ELGA PRODUCTS, LTD.
Conductivity.
ELLIOTT NUCLEONICS, LTD.
ENGELHARD INDUSTRIES, LTD.
Specials.
ENGLISH CLOCK SYSTEMS.
Time recording equipment.
ETHER, LTD.
Temperature, process.
EVERSHED AND VIGNOLES, LTD.
Pressure, level, specific gravity, purity.
FIELDEN ELECTRONICS, LTD.
Level temperature, pressure, flow.
FINDLAY AND CO.
Counting (A).
FIRTH CLEVELAND INSTRUMENTS, LTD.
Flow counters, indicators, controllers.
FISHER GOVERNOR CO., LTD.
Level, pressure, controllers.
FLIGHT REFUELLING, LTD.
Gas flow indicators, air test facilities.
FOXBORO-YOXALL, LTD.
Temperature, flow, level, pressure, humidity.
GORDON, JAMES, AND CO., LTD.
Level indicators.
GRAVINER MANUFACTURING CO., LTD.
Thermostats; temperature switches, control.
HARCOURT, DAVID, LTD.
Pressure, vacuum; thermometers, vapour tension.
HEATH, HICKS AND PERKEN, LTD.
Temperature indicating, recording; meteorological.
IGRANIC ELECTRIC CO., LTD.
Timers, liquid level.
INFRA RED DEVELOPMENT CO., LTD.
Micromanometers.
INTEGRA, LEEDS AND NORTHRUP, LTD.
Measuring, recording, controlling.

## 183 INSTRUMENTS, PROCESS CONTROL (contd.)

**INTEGRAL, LTD.**
Flowmeters, data display, density, transmitters, counters.

**INTERNATIONAL GAS DETECTORS, LTD.**
Gas detectors; $CO_2$;, hydrogen, alarms.

**IONIC INSTRUMENTS (LONDON), LTD.**
Liquid level, contents, temperature; prototypes.

**K.D.G. INSTRUMENTS, LTD.**
Tank contents, pressure, thermometry.

**KELVIN AND HUGHES (INDUSTRIAL), LTD.**
Boiler-house.

**KENT, GEORGE, LTD.**
Differential-pressure.

**K.G.M. ELECTRONICS, LTD.**
Speed; remote control.

**KILPATRICK, JAMES, AND SON, LTD.**
Contracting services.

**KLINGER, RICHARD, LTD.**
Liquid level.

**LACY-HULBERT AND CO., LTD.**
Pressure, vacuum.

**LAND PYROMETERS, LTD.**
Pyrometers; surface, suction, radiation.

**LEA RECORDER CO., LTD., THE.**
Boiler-house.

**LEEDS METER CO., LTD., THE.**
Water, allied liquids, recording instruments.

**LINTRONIC, LTD.**
Hot-film anemometer, turbulence; liquid, gas.

**LIQUID SYSTEMS, LTD.**
Flow.

**LOCK, A. M., AND CO., LTD.**
Level indicators, temperature, pH controllers.

**MALONE INSTRUMENT CO., LTD., THE.**
Contents, level, vacuum, distance thermometers.

**MANCHESTER WATER METER CO., LTD., THE.**
Oil, water, etc.

**McKELLEN, S. D., LTD.**

**MEASUREMENT, LTD.**
"Shoflo" indicator.

**MECHANISM, LTD.**
Electro-mechanical; pressure.

**MINERVA LABORATORIES (INSTRUMENTS), LTD.**
Specialized electro-mechanical.

**MONRO, R. W., LTD.**
Anemometers.

**NAPIER, D., AND SON, LTD.**
Interlock units.

**NEGRETTI AND ZAMBRA, LTD.**
Temperature, pressure, humidity, level; transmission control.

**NEILL, WM., AND SON (ST. HELENS), LTD.**
Level indicators, etc.

**NEW WESTERN (ENGINEERING), LTD.**
Contractors.

**NORTHERN SCIENTIFIC EQUIPMENT, LTD.**
Specials.

**PALATINE TOOL AND ENGINEERING CO. (SURBITON), LTD.**
Flowmeters.

**PARMEKO, LTD.**
Furnace; photo-cell, magnetic amplifiers.

**PEEBLES, BRUCE, AND CO., LTD.**
Electronic systems; equipment.

**PLATON, G. A., LTD.**
Controllers, alarms; flow.

**PROCESS CONTROL GEAR, LTD.**
Thermostats, all types.

**RATZER, JOHN H., LTD.**
Electronic timers.

**ROBINSON, D., AND CO.**
Sequence controllers, process timers.

**ROBINSON, F. C., AND PARTNERS, LTD.**
Batching; level controllers.

**ROTAMETER MANUFACTURING CO., LTD.**
Flow meters, alarms; density, level gauges.

**ROTHERHAM AND SONS, LTD.**
Timers, sequence controllers, fuel gauges.

**SAUTER CONTROLS, LTD.**
Pressure-, thermo-, level-, flow-stats; timers.

**SHORT AND MASON, LTD.**
Temperature, pressure, humidity, flow, viscosity; prototypes.

**SIGMA INSTRUMENT CO., LTD.**
Automatic inspection, sorting machines.

**SPIRAX-SARCO, LTD.**
Thermostatic control.

**STURDY ELECTRIC CO., LTD.**
Dispersion meters, batch counters.

**SYKES, W. R., INTERLOCKING SIGNAL CO., LTD.**
Specialized equipment, customers' specifications.

**TECHNE (CAMBRIDGE), LTD.**
"Tempunit" temperature control unit.

**TEDDINGTON INDUSTRIAL EQUIPMENT, LTD.**
Pressure, vacuum; thermostats; development.

**TELEKTRON (GT. BRITAIN), LTD.**
Systems engineers.

**TELEMETERS, LTD.**
Telemetering, automatic sequence controllers.

**TEST EQUIPMENT, LTD.**
Remote control.

**THERMOCONTROL INSTALLATIONS CO., LTD.**
Humidity, pressure, temperature; alarms, controllers.

**THOMPSON, JOHN, INSTRUMENT CO., LTD.**
Temperature, flowmeters, manometers, gauges.

**TRIST, RONALD, AND CO., LTD.**
"Mobrey," magnetic, level, switches.

**UNITY HEATING, LTD.**
Temperature.

**UNIVERSAL CONTROL EQUIPMENT, LTD.**
Conductivity; safety controls; interlocks.

**VENNER ELECTRONICS, LTD.**
Transistorized equipment-digital nature, frequency, time.

**VERNON INSTRUMENT CO., LTD.**
Metrology; precision components, specials.

**WALTER KIDDE CO., LTD., THE.**
Liquid level indicators.

**WAYMOUTH GAUGES AND INSTRUMENTS, LTD.**
Liquid; temperature measurement.

**WEST INSTRUMENT, LTD.**
Temperature.

**WEYERS BROS., LTD.**
Precision engineers.

**WHITE AND RICHES, LTD.**
Development.

**WIDGIERY DEVELOPMENTS, LTD.**
Manometers; pressure, vacuum.

**W.S. ELECTRONICS (PRODUCTION), LTD.**

**WYKEHAM, W., AND COMPANY, LTD.**
Controllers, recorders, gas analysis, computers, counters (A).

## 184 INSTRUMENTS, TEST

*see also MECHANICAL TEST*

**ADVANCE COMPONENTS, LTD.**
Signal generators, "Q" meters, valve voltmeters.

**ALLIED ELECTRONICS, LTD.**
Insulation measuring, ammeters, high voltage generators.

**ANDEC, LTD.**
D.C., audio, R.F. equipment.

**ARMSTRONG WHITWORTH, SIR W. G., AIRCRAFT, LTD.**
Amplifiers, oscilloscopes, oscillators, power units; development.

**AVO, LTD.**
Transistor analysers.

**BRITISH COMMUNICATIONS CORPORATION, LTD.**
V.H.F. communication.

**BUTLER, HOWARD, LTD.**

**BUTLER RADIO MFG. CO. (ROCHESTER), LTD.**
Prototype electronic.

**CAWKELL RESEARCH AND ELECTRONICS, LTD.**
Oscilloscopes, pulse generators, supplies, delay units.

**CINEMA-TELEVISION, LTD.**
Pulse generators, oscilloscopes, power packs, timers.

**COSSOR INSTRUMENTS, LTD.**
Oscillographs, pulse generators, transistorised power supplies.

**CROMPTON PARKINSON, LTD.**

**CROYDON PRECISION INSTRUMENT CO.**
Bridges, resistance boxes.

**CURRAN, JOHN, LTD.**
Specials, neutron diffraction spectrometers, collimators.

**DAVIS, JOHN, AND SON (DERBY), LTD.**
Barometers, anemometers, water gauges.

**DAVISON AND CO. (HEXHAM), LTD.**
Vacumeters.

**DAWE INSTRUMENTS, LTD.**
Pulse generators.

**DORAN INSTRUMENT CO., LTD.**

**DYNATRON RADIO, LTD.**
Pulse generators, power units.

**ELECTRONICS (PRODUCTION), W. S., LTD.**
Transistor sets, telemetry U.H.F., V.H.F. units.

**ERICSSON TELEPHONES, LTD.**
Timers, pulse generators, counting units.

**EVANS ELECTROSELENIUM, LTD.**
Blood cell counter.

**EVERSHED AND VIGNOLES, LTD.**
Ohmmeters, voltmeters, ammeters, polarographs.

**FAIREY AVIATION CO., LTD., THE.**
Nuclear magnetic resonance spectrometer.

**FLEISCHMANN (LONDON), LTD.**
High vacuum.

**FLEMING RADIO (DEVELOPMENTS), LTD.**
Pulse generator.

**FURZEHILL LABORATORIES, LTD.**
Oscilloscopes, voltmeters, frequency, standards, pulse counters.

**GENEVAC, LTD.**
Vacuum.

**GLOSTER AIRCRAFT CO., LTD.**
Pulse generators, profile indicators.

**GOODMANS INDUSTRIES, LTD.**

**GRESHAM TRANSFORMERS, LTD.**

**HARRIS, PHILIP, LTD.**
Scientific.

**HATFIELD INSTRUMENTS, LTD.**
Signal generators, oscillators, attenuators, voltmeters.

**HILGER AND WATTS, LTD.**
Spectrographs, spectrophotometers, absorptiometers.

**KAPPA MOISTURE METERS, LTD.**
Moisture meters.

**LION ELECTRIC DEVELOPMENTS, LTD.**
Special units, encapsulated circuits.

**LIVINGSTON LABORATORIES, LTD.**
Oscilloscopes, signal generators.

**LYONS, CLAUDE, LTD.**
Automatic voltage regulators: stabilized supplies.

**MARCONI INSTRUMENTS, LTD.**
Equipment, bridges, voltmeters, etc.

**MEASURING INSTRUMENTS (PULLIN), LTD.**

**MERCER, THOMAS, LTD.**
Chronometers, recorder units, comparators, test sets.

**MICROWAVE INSTRUMENTS, LTD.**
Waveguide components, power supplies; special purpose.

**MILES HIVOLT, LTD.**
Insulation testing, high voltage measuring.

**MUIRHEAD AND CO., LTD.**
Oscillators, analysers, phasemeters, bridges, tachometer generators.

**MULLARD EQUIPMENT, LTD.**
Analysers, pulse generators, oscilloscopes, magnetic resonance.

**NALDER BROS. AND THOMPSON, LTD.**
Dynamometers, ammeters, voltmeters, wattmeters, frequency.

**NASH AND THOMPSON, LTD.**

**NEO ELECTRICAL INDUSTRIES, LTD.**
"Neo-Maintest"; high voltage indicators.

**NEWPORT INSTRUMENTS (SCIENTIFIC AND MOBILE), LTD.**
Electronic, magnetometers.

**PRECISION INSTRUMENT REPAIR CO.**
Meteorological.

**PYE, W. G., AND CO., LTD.**
High resistance, pH, chromatograph bridges; amplifiers.

**RACAL ENGINEERING, LTD.**
Digital frequency meters, counters, timers, tachometers.

**RADIO-AIDS, LTD.**
Commercialisation from prototypes.

**RANK CINTEL, LTD.**
Pulse generators, C.R. tubes, particle counting.

**RECORD ELECTRICAL CO., LTD., THE.**
Tachometers.

**REID, A., MANUFACTURING CO., LTD.**
Pulse generators, spectrometers; P.M. holders.

**RESEARCH AND CONTROL INSTRUMENTS, LTD.**
Signal generators, oscilloscopes, d.c. amplifiers, bridges.

**RIVLIN INSTRUMENTS, LTD.**
Design, fabrication.

**ROBINSON, F. C., AND PARTNERS, LTD.**
Timers, power supplies, voltmeters, bridges.

**RUNDLE, A. (UPPER NORWOOD), LTD.**
Special purpose machines, designs, mechanisms.

**SANGAMO WESTON, LTD.**

**SANDERS, W. H. (ELECTRONICS), LTD.**
Microwave.

**SAVAGE, W. BRYAN, LTD.**
Vibrators, amplifiers, G. meters, oscillators.

**SERVOMEX CONTROLS, LTD.**
Servo test, transfer function analysers.

**SHACKMAN, D., AND SONS.**
Oscilloscope recording cameras.

**SHANDON SCIENTIFIC CO., LTD.**
Camera microscope, chromatography, electrophoresis.

**SHORT BROS. AND HARLAND, LTD.**
Control system analysers, oscillators.

## 184 INSTRUMENTS, TEST (contd.)

SOLARTRON ELECTRONIC GROUP, LTD.
Oscilloscopes.

SOUTHERN INSTRUMENTS, LTD.
Oscilloscopes, recording cameras; absorption, turbidity meters.

TAYLOR ELECTRICAL INSTRUMENTS, LTD.
Test meters, oscilloscopes, signal generators.

TELEMECHANICS, LTD.
Frequency meters, insulation test, development facilities.

TRUMETER CO., LTD.
Counters.

UNION RADIO CO., LTD.
Interference measuring; specials.

WAYNE KERR LABORATORIES, LTD., THE.
Bridges, vibration meters, electronic micrometers, oscillators.

WEST LONDON IRON AND WIRE WORKS, LTD.
Pulse generators, oscilloscopes, power units, timers.

WINSTON ELECTRONICS, LTD.
Spectrographic monitor, counting, timing equipment, (A).

ZEAL, G. H., LTD.
Thermometers, hydrometers.

## 185 INSULATION, ELECTRICAL

ATTWATER AND SONS, LTD.
Mica importers, cutters.

BRITISH INSULATED CALLENDER'S CABLES, LTD.

BULLERS, LTD.
Porcelain, supporting ironwork.

DOULTON INDUSTRIAL PORCELAINS, LTD.
Porcelain.

EVODE, LTD.
Adhesive tape.

IMPERIAL CHEMICAL INDUSTRIES, LTD.

IOCO, LTD.
"Ioco" soft products.

LODGE PLUGS, LTD.
Ceramic.

MICA AND MICANITE SUPPLIES, LTD.
Mica.

MICALECTRIC, LTD.
Mica plates, forms.

MICANITE AND INSULATORS CO., LTD., THE.
"Mica, micanite, Samica, Paxolin, Panilax, Armatite."

MINNESOTA MINING AND MANUFACTURING CO., LTD.
"Scotch" tapes.

PERMALI, LTD.
Laminates, densified wood; glass fibre, reinforced.

STEEL, J. M., AND CO., LTD.

SYMONS, H. D., AND CO., LTD.
Flexible.

TUFNOL, LTD.
"Tufnol."

## 186 INSULATION, THERMAL

BAYLEY, F. S., CLANAHAN AND CO., LTD.
Ceramics.

BELL'S ASBESTOS AND ENGINEERING, LTD.

BRITISH REFRASIL CO., LTD., THE.
Low boron silica, lightweight textile.

CAPE ASBESTOS CO., LTD.
"Caposite," "Caposil," "Pluto," "Capoplastic," "Rocksil."

CAPE BUILDING PRODUCTS, LTD., THE.
"Asbestolux" insulation board.

CHEMICAL AND INSULATING CO., LTD., THE.
Magnesia, "Dextramite," calcium silicate, armouring, finishing.

CONSETT IRON CO., LTD.
High temperature refractories; zircon, zirconia.

CORRANCE AND YUILL, LTD.
Asbestos products.

CURTIS, A. L., (OMX), LTD.
Refractory materials.

DARLINGTON INSULATION CO., LTD., THE.
Contractors.

DAY, J., AND CO. (DERBY WORKS), LTD.
"Daystar," 1,000°C; coverings.

DELANEY GALLAY, LTD.
Thermal, high temperature, lightweight.

DRAFTSELL, LTD.

EXPANDED RUBBER CO., LTD.
"Onazote."

GENERAL REFRACTORIES, LTD.

HARGREAVES, HENRY, AND SONS, LTD.

INSULATALL SERVICES, LTD.
Thermal and sound contractors.

JABLO PLASTICS INDUSTRIES, LTD.
"Jablite"; "Jablex" lightweight expanded plastics.

JOHNS-MANVILLE CO., LTD.
"Thermoflex" fibre, sheathed s.s.; "Centritex" rockwool.

KENYON, WILLIAM, AND SONS, LTD.

KITSON'S INSULATIONS, LTD.
Plastics, asbestos, mineral, glass fibre.

MALLINSON, WILLIAM, AND SONS, LTD.
Panels.

MOLER PRODUCTS, LTD.
"Fosalsil" bricks, aggregates; plastics, composition.

NEWALLS INSULATION CO., LTD.
Contractors, manufacturers; sound.

ONAZOTE INSULATION CO., LTD.

PERMALI, LTD.
Cast resin.

P.H. THERMAL PRODUCTS.
Jackets, bandages, lagging.

REFRACTORY MOULDINGS AND CASTINGS, LTD.
Refractories; special shapes, ware.

ROBERTSON, J. R. A.,

SPRAYED INSULATIONS, LTD.
Sprayed asbestos, etc.

STILLITE PRODUCTS, LTD.
Mineral wool.

SYDDALL, ARTHUR, (GRANTHAM,) LTD.
Asbestos sheeting.

THERMAL SYNDICATE, LTD., THE.
Refractories, "Vitreosil," "Spectrosil."

TOMLINSONS (ROCHDALE), LTD.
"Seelheet" panels.

UNILOCK PARTITIONS, LTD.
Expanded polystyrene slabs.

VERSIL, LTD.
Glass fibre.

## 187 IRRADIATION LABORATORY
*see also ACCELERATORS*

METROPOLITAN-VICKERS ELECTRICAL CO., LTD.
Linear accelerator beam facilities.

## 188 IRRADIATION UNITS

HOBSON, H. M., LTD.
Honeycomb.

METROPOLITAN VICKERS ELECTRICAL CO. LTD.
"Newton-Victor Orbitron" therapy

NUCLEAR ENGINEERING, LTD.
Gamma ray therapy units.

## 189 ISOTOPE APPLICATIONS

BALDWIN INSTRUMENT CO., LTD.
Beta, gamma thickness gauges.

BURNDEPT, LTD.
Portable thickness gauge, radiation switch.

DAVY AND UNITED ENGINEERING CO., LTD.
Non-contacting metal thickness gauges.

EKCO ELECTRONICS, LTD.
Thickness, density, wear, pipe wall gauges.

HENDREY RELAYS, LTD.
Bore hole survey.

ISOTOPE DEVELOPMENTS, LTD.
Thickness, liquid level, density gauges, gamma switch, package monitors.

LABGEAR, LTD.
Consultancy service.

MADDOCK, J. O., (LONDON).
Consultants.

MINERVA DETECTOR CO., LTD., THE.
Fire alarms.

## 190 ISOTOPES

A.E.R.E., HARWELL.
Irradiated materials; short lived, high activity sources.

RADIOCHEMICAL CENTRE, THE.
Processed; sealed sources; labelled compounds.

# J

## 191 JOINTINGS; Packings

B.B. CHEMICAL CO., LTD.
"Bostik" adhesives; coatings, compositions.

BELDAM ASBESTOS CO., LTD.

BELL'S ASBESTOS AND ENGINEERING, LTD
Asbestos/fluon.

COOPER AND CO. (BIRMINGHAM), LTD.
Croid No. 65 machine fixing glue.

CRANE PACKING, LTD.

ENGLISH ASBESTOS (SALES), LTD.
Asbestos cloths, yarns, tapes.

EXPANDER RUBBER CO., LTD.
"Rubazote" sheeting, gaskets.

GUEST KEEN AND NETTLEFOLDS (MIDLANDS), LTD.

HOLLYWOOD, WM., AND CO.
Asbestos.

HOWARD BROTHERS.
Compressed asbestos fibre.

IMPERIAL CHEMICAL INDUSTRIES, LTD.
"Fluon"; gaskets.

KEIRBY, EDWARD, AND CO., LTD.
All materials; asbestos products.

KLINGER, RICHARD, LTD.
Compressed asbestos; PTFE, silicone rubber.

MINNESOTA MINING AND MANUFACTURING CO., LTD.
"Scotch" splicing: tapes.

NORTON, F. A., AND SONS, LTD.
Lead washers.

PERDECK SOLDER PRODUCTS, LTD.
Solder, fluxes.

PIONEER OILSEALING MOULDING CO., LTD.
Hydraulic.

ROBERTS, A., AND CO. (HECKMONDWIKE), LTD.
Asbestos, textiles, etc.

RUBBAGLAS, LTD.
"Rubbaglex" sheeting.

TURNER BROTHERS ASBESTOS CO., LTD.
Asbestos, textiles, "Permanite," compressed asbestos.

UNITED STATES METALLIC PACKING CO., LTD.
Metallic.

UNIVERSAL METALLIC PACKING CO., LTD., THE.
Metallic, carbon.

WALKER, JAMES, AND CO., LTD.

WELLWORTHY, LTD.
"Wellseal" compound.

WHITBY AND CHANDLER, LTD.
Compressed asbestos, PTFE, PVC.

WITTY AND WYATT, LTD.
Asbestos gaskets, laggings.

WOOD BROS. AND CO. (GASKETS), LTD.
Gaskets.

WRIGHT, THOMAS, (BFD.), LTD.
Felt, leather, paper; washers.

# L

## 192 LABORATORY EQUIPMENT

AMAL, LTD.
Bunsen burners.

BAIRD AND TATLOCK (LONDON), LTD.

BRYANS AEROQUIPMENT, LTD.
Centrifuges, manometers, vacuum chambers, material cabinets.

CAMLAB (GLASS), LTD.
Furnishers; ovens, water baths, glass tubing.

CUTHBERT, RALPH, LTD.

CYGNET JOINERY, LTD.

ELECTROCHEMICAL LABORATORIES.
Gas purifiers, polarographs.

ENGELHARD INDUSTRIES, LTD.
General; platinum crucibles.

GALLENKAMP, A., AND CO., LTD.

GREY AND MARTEN, LTD.
Lead benches.

GRIFFIN AND GEORGE (SALES), LTD.

LABORATORY APPARATUS AND GLASS BLOWING CO.
Glassware, rubber, plastics, s.s.

LABORATORY EQUIPMENT (LONDON), LTD.
Climatic cabinets, ovens.

## 192 LABORATORY EQUIPMENT (contd.)

**LABORATORY THERMAL EQUIPMENT, LTD.**
Ovens, baths, humidity cabinets.

**OERTLING, L., LTD.**
Balances, ultra mirco, semi-automatic.

**PASCALL ENGINEERING CO., LTD.**

**PLANER, G. V., LTD.**
Electrical materials.

**QUICKFIT AND QUARTZ, LTD.**
Interchangeable glassware.

**RESISTANT EQUIPMENT, LTD.**

**RHODES, GILL AND CO., LTD.**
Autoclaves.

**SAUNDERS-ROE (ANGLESEY), LTD.**
Fume cupboards.

**SIEREX, LTD.**
X-ray crystallography, dose meters, oscillographs (A).

**STANTON INSTRUMENTS, LTD.**
Balances.

**STURTEVANT ENGINEERING CO., LTD.**
Crushing machinery.

**TOWNSON AND MERCER, LTD.**
Precision thermostat bath.

**UNIBRIX RADIATION SHIELDINGS, LTD.**
Hot laboratory benches.

**VICSONS, LTD.**
Glassware, apparatus, tubing, plastics, rubber.

**WEBB, WILLIAM A., LTD.**
Aperiodic, analytical, micro-chemical precision balances.

**WILFLO PRODUCTS, LTD.**

**WINKWORTH MACHINERY, LTD.**
Mixers, blenders.

**X-LON PRODUCTS.**
Plastics ware.

## 193 LEAD

*see also SHIELDING BLOCKS, MATERIALS*

**ANTI-ATTRITION METAL CO., LTD., THE.**
Anti-friction white metals.

**ASSOCIATED LEAD MANUFACTURERS, LTD.**
Shielding bricks, containers.

**BADDELEY, D. S., ENG. CO., LTD.**
Burning apparatus.

**BIRWELCO, LTD.**
Lined tanks.

**B.M.B. (SALES), LTD.**

**BRITISH LEAD MILLS, LTD.**
Bricks, canister filling.

**BRUNTON AND CO., LTD.**
Castings, vessels, bricks.

**CHANCE-PILKINGTON OPTICAL WORKS.**
Glass blocks.

**ENTHOVEN SOLDERS, LTD.**
Tubes, containers.

**FOWLER, H. G., AND CO., LTD.**
Fabricated linings, rooms, vessels, pipes.

**GRAZEBROOK, M. AND W., LTD.**
Linings, containers.

**GREY AND MARTEN, LTD.**
Castings, fillings, fabrications, pots, linings.

**JENKINS, ROBERT, AND CO., LTD.**
Lined vessels.

**JENKINSON, W. G., LTD.**
Sheet fabricated to 4 in. thick; bonded.

**LEAD DEVELOPMENT ASSOCIATION.**
Consultants.

**LEAD WOOL CO., LTD., THE.**
Bricks, washers, rings, wool, wire, tape.

**LEES, J. B. AND S., LTD.**
Coated steel strip.

**LUNEVALE PRODUCTS, LTD.**
Compounds.

**MILLS PACKARD CONSTRUCTION CO., LTD.**
Fabrications.

**NEILL, WM., AND SON (ST. HELENS), LTD.**
Sheet lining work.

**NORTON AND RIDING (YORKS.), LTD.**
Burners, shop or site.

**OPENSHAW, WILLIAM, LTD.**
Lining, coverings, fabrications.

**PODMORE, W., AND SONS, LTD.**
Silicates.

**SAVAGE AND PARSONS, LTD.**
Shielding.

**SMEATON AND SONS, LTD.**
Installations.

**TOWERS, J. W., AND CO., LTD.**
Bricks, castles.

## 194 LIFTING GEAR

*see also CRANES, MECHANICAL HANDLING*

**ALLEN, A. H., AND CO. (ENGINEERS), LTD.**
Hand operated equipment.

**ANDERSON CLYDE ENGINEERS, LTD.**
Mobile gantries.

**BARKER, JOHN, AND SONS (ENGINEERS), LTD.**
Hoists, lifts.

**BRITISH ELECTRICAL REPAIRS, LTD.**
Screw jacks, 200 ton.

**FELCO HOISTS, LTD.**
Hoists, blocks, jacks.

**FELLOWS BROS., LTD.**
Pulley blocks, jacks.

**GLOBE PNEUMATIC ENG. CO., LTD.**
Pneumatic hoists.

**GOODWIN, ARNOLD, LTD.**
Hoists, jacks, rams.

**LAKE AND ELLIOT, LTD.**
Hydraulic jacks.

**MARTONAIR, LTD.**
Pneumatic hoists.

**MOORE, W. AND E., LTD.**
Winches, hoists, slings.

**SOWERBYS (CONTRACTORS), LTD.**
Jacks, blocks, winches, lifts.

**STEVEN, A. AND P., LTD.**
Hoists, lifts.

**TIRFOR, LTD.**
Lifting gear to 3 tons.

**WICKHAM ENGINEERING CO., LTD.**
Hoists.

**YOUNGS (LIFTING APPLIANCES), LTD.**
Hydraulic cylinders, rams, jacking equipment.

## 195 LUBRICANTS

**ABRIL INDUSTRIAL WAXES, LTD.**
Extrusion, mould release.

**ACHESON COLLOIDS, LTD.**
Colloidal graphite; molybdenum disulphide.

**MOBIL OIL CO., LTD.**
Oils, greases.

**PAUL, K. S., (MOLYBDENUM DISULPHIDE), LTD.**
Molybdenum disulphide, solid films; treatment.

**REGENT OIL CO., LTD.**
"Caltex" oils, greases.

**ROCOL, LTD.**
Molybdenum disulphide, oils, core locking, cutting cpds.

**SHELL-MEX AND B.P., LTD.**
Radiation resistant, greases; hydraulic fluids, oils.

**VIGZOL OIL CO., LTD., THE.**
Oils, greases, allied products.

**WAKEFIELD-DICK INDUSTRIAL OILS, LTD.**
Radiation resistant.

## 196 LUBRICATION

**CENTRALUBE, LTD.**
Centralized, remotely controlled equipment.

**GREASE APPLIANCE CO., LTD.**
Equipment, fittings.

**LIQUID SYSTEMS, LTD.**
Systems, ancilliary equipment.

**LOXHAMS ENGINEERING WORKS, LTD.**
"Ionic" mechanical lubricators.

**NORGREN, C. A., LTD.**
Oil fog, micro-fog.

**TECALEMIT, LTD.**
Automatic, hand.

# M

## 197 MACHINE TOOLS

**ADAM MACHINE EQUIPMENT, LTD.**

**ADCOCK AND SHIPLEY, LTD.**

**ARCHDALE, JAMES, AND CO., LTD.**

**ARGER MACHINERY, LTD.**

**AUTOFLOW ENGINEERING, LTD.**
Diamond; glass.

**BARNSLEY, JOHN, AND SONS, LTD.**
Specials.

**BROWN, DAVID, INDUSTRIES, LTD.**

**BRONX ENGINEERING CO., LTD.**

**B.S.A. TOOLS, LTD.**

**BURTON, GRIFFITHS AND CO., LTD.**
Agent.

**CINCINNATI MILLING MACHINES, LTD.**

**CRAVEN BROTHERS (MANCHESTER), LTD.**

**CROSTHWAITE FURNACES AND SCRIVEN MACHINE TOOLS, LTD.**

**CROWTHORN ENGINEERING CO., LTD., THE.**

**DRUMMOND-ASQUITH (SALES), LTD.**
Agent.

**EDWARDS, F. J., LTD.**

**ELECTRO-HYDRAULICS, LTD.**
For fuel element manufacture.

**ELGAR MACHINE TOOL CO., LTD.**
Agents.

**ENGLISH STEEL TOOL CORPORATION, LTD.**

**EVANS, J., AND SON (PORTSMOUTH), LTD.**
Special purpose for processing, research laboratories.

**FAIREY AVIATION CO., LTD., THE.**

**FIELDING AND PLATT, LTD.**

**FINLAY ENGINEERING, LTD.**

**FOSTER YATES AND THOM., LTD.**

**FROST (ROCHDALE), LTD.**

**GAYDON, H. A., AND CO., LTD.**

**GRIGG, CHARLES S. W., LTD.**

**HARDINGE MACHINE TOOLS, LTD.**

**HEATHWAY MACHINERY CO., LTD.**
Glass working lathes.

**KENNEDY, W., LTD.**

**McKELLEN, S. D., LTD.**

**MOLLART ENGINEERING CO., LTD., THE.**
Specials.

**MONKS AND CRANE, LTD.**

**NATIONAL PLASTICS (SALES), LTD.**
Compression, injection, extrusion, moulders.

**NOBLE AND LUND, LTD.**

**NORTON, SIR JAMES FARMER, AND CO., LTD.**

**PILOT WORKS, LTD.**

**RICHARDS, GEORGE, AND CO., LTD.**

**RJH TOOL AND EQUIPMENT CO., LTD., THE.**

**SCOTTISH MACHINE TOOL CORPORATION, LTD.**

**SMITH, HUGH, AND CO. (POSSIL), LTD.**
Heavy.

**SOAG MACHINE TOOLS, LTD.**

**TALBOT TOOL CO., LTD.**

**WADKIN, LTD.**
Non-ferrous metals.

**WICKSTEED, CHARLES AND CO., LTD.**

**WILD, THOS. C., (MACHINERY), LTD.**

**WINDLEY BROS., LTD.**

**WILLIAMS, H., AND SON, LTD.**

**WRIGHT ELECTRIC MOTORS (HX), LTD.**

## 198 MACHINING

**BIRFIELD INDUSTRIES, LTD.**

**BOREMASTER OF KENILWORTH.**
Jig boring specialists.

**B.S.A. TOOLS, LTD.**
Special studies.

**CRAVEN BROTHERS (MANCHESTER), LTD.**
Jig, tool; jig boring.

**DAVISON AND CO. (HEXHAM), LTD.**

**DELAPENA AND SON, LTD.**
Precision honing equipment.

**DIXON-BATE, B., LTD.**
Repetition to vacuum standards.

**DOWTY NUCLEONICS, LTD.**
Under "clean conditions."

**FARR, EDWARD, LTD.**

**GAYDON, H. A., AND CO., LTD.**
Light.

**GRAZEBROOK, M. AND W., LTD.**
Heavy assembly.

**HALL BROTHERS (NETHERTON), LTD.**

**HARLAND AND WOLFF, LTD.**

**HARPER, JOHN, AND CO., LTD.**

**KINGSTON INSTRUMENT CO., LTD.**
Shop facilities.

**MERCER, THOMAS, LTD.**
Special mechanisms, gears, racks.

**M.H.H. ENGINEERING CO., LTD.**
Automatic 2 in., capstan 3 in., chucking 14 in.

**MILES DEVELOPMENT PRODUCTS, LTD.**
General; s.s.

**MILLS, GEORGE, (ENGINEERS), LTD.**
Spline, form grinding.

## 198 MACHINING (contd.)

**MOLLART ENGINEERING CO., LTD., THE.**
Precision assemblies.

**MORRIS, B. O., LTD.**
Precision sub-contract engineering.

**MOUNTFORD, FREDK., (BIRMINGHAM), LTD.**
Repetition parts; s.s.

**PIPEWORK AND ENGINEERING (BRISTOL), LTD.**
Capstan, centre lathe; milling; shaping; grinding.

**POOLE, R. A., AND CO. (SUTTON), LTD.**
Auto, capstan; s.s., aluminium, nylon, etc.

**PREMIER SCREW AND REPETITION CO., LTD.**
Repetition work.

**RHYMNEY ENGINEERING CO., LTD.**
High quality.

**ROSS, COURTNEY AND CO., LTD.**
Capstan, automatic turned parts; presswork.

**ROSS, LTD.**
General; plating anodising, metal spraying.

**RUBERY, OWEN AND CO., LTD.**
Repetition.

**RYDER, THOS., AND CO. (MANCHESTER), LTD.**
General assembly; precision work.

**SCOTTS ENGINEERING (NEWPORT), LTD.**
Precision assemblies to 10 ton.

**SCREW MACHINE PRODUCTS, LTD.**
Repetition auto components; assemblies; design.

**SEALEY, ENGINEERING CO., LTD.**
Precision.

**SHEEPBRIDGE EQUIPMENT, LTD.**
General, gear cutting.

**SHERWOOD INSTRUMENTS, LTD.**
Capstan turned parts to 1¼ in. dia.

**SMITH, W. H., AND CO. (WHITCHURCH), LTD.**

**TALBOT STEAD TUBE CO., LTD.**
S.s.

**THREADWELL, J. J., AND SONS, LTD.**
Precision engineers; finishing, polishing, heat-treatment.

**UNITED STATES METALLIC PACKING CO., LTD.**
Medium.

**VERNON INSTRUMENTS CO., LTD.**
Precision; design.

**WESTERN DETAIL MANUFACTURERS, LTD.**
Precision work.

**WESTERN MANUFACTURING (READING), LTD.**
Gear cutting, heat treatment, plating.

## 199 MAGNESIUM

**ACCLES AND POLLOCK, LTD.**
Magnox fuel cans.

**ALMIN, LTD.**
Alloy ingots.

**BIRMETALS, LTD.**
Alloys, all wrought forms.

**BIRMINGHAM ALUMINIUM CASTING (1903) CO., LTD.**

**CRITTALL-LUXFER, LTD.**
Castings, forgings.

**HIGH DUTY ALLOYS, LTD.**
Alloy forgings.

**IMPERIAL CHEMICAL INDUSTRIES, LTD.**

**LIGHT-METAL FORGINGS, LTD.**
Magnox forgings.

**MAGNESIUM ELEKTRON, LTD.**

**STERLING METALS, LTD.**

**T.I. NUCLEAR ENGINEERING, LTD.**
Fuel element sheaths.

## 200 MAGNETS

**AYLING NUCLEAR EQUIPMENT CO.**
Cyclotron components.

**BRITISH ELECTRICAL REPAIRS, LTD.**
Electro, solenoids.

**BROWNINGS ELECTRIC CO., LTD.**

**DARWINS, LTD.**
Permanent.

**MAGNETIC EQUIPMENT CO., LTD.**
Laboratory; "Magcodrill" drillstand; separators.

**MOORES (BOURNEMOUTH), LTD.**
Special.

**MULLARD, LTD.**
"Ticonal" permanent ferrites.

**MUREX, LTD.**
Sintered permanent.

**NEILL, JAMES, AND CO. (SHEFFIELD), LTD.**
Permanent; tools, chucks.

**NEWPORT INSTRUMENTS (SCIENTIFIC MOBILE), LTD.**
Electro; standard, custom-built.

**RAPID MAGNETIC MACHINES, LTD.**
Extracting, separating; lifting equipment.

**TURTON BROS. AND MATTHEWS, LTD.**
Permanent.

**UNIVERSAL CONTROL EQUIPMENT, LTD.**
Electromagnets.

**WILFO PRODUCTS, LTD.**

## 201 MECHANICAL HANDLING PLANT

**ABELSON AND CO. (ENGINEERS), LTD.**
Concrete handling derricks.

**ACME VENTILATING, LTD.**

**ALLEN, W. G., AND SONS (TIPTON), LTD.**

**ALMIN, LTD.**
Equipment; aluminium containers, rods, sections.

**ANDREWS AND PLATT (ENGINEERS), LTD.**
Equipment; chains, cranes, gantries, trolleys.

**ANGEL TRUCK CO., LTD.**
Truck, trolleys, conveyors.

**BIRMINGHAM AND BLACKBURN CONSTRUCTION CO., LTD.**
Plateforms; special purpose conveyors.

**BRAMIGK AND CO., LTD.**

**BROWN, N. W., AND PARTNERS, LTD.**
Materials, equipment.

**COLLIS, J., AND SONS, LTD.**
Equipment, trucks, stackers, conveyors.

**CONSTRUCTIONAL ENGINEERING CO., LTD., THE.**

**CONVEYANCER FORK TRUCKS, LTD.**
Fork trucks, 2,000–8,000 lb; pallets, attachments.

**CORBETT, R. H., AND CO., LTD.**

**DOUGLAS EQUIPMENT, LTD.**
Tractors, towing, shunting, marshalling.

**DRIVER, GEO., AND SON, LTD.**
Conveyors, elevators, screens, weighing, dispensing.

**DUSTRACTION, LTD.**
Pneumatic conveyors.

**ECCLES (BIRMINGHAM), LTD.**
Equipment, trailers, stackers, gantries.

**ELECTRO-HYDRAULICS, LTD.**

**ENDECOTTS (FILTERS), LTD.**
Test shakers; sieves.

**FARRAR BOILERWORKS, LTD., THE.**

**FISHER AND LUDLOW, LTD.**
Conveyors, pallets.

**FLEXELLO CASTORS AND WHEELS, LTD.**
Castors, wheels.

**FREEMAN TAYLOR MACHINES, LTD.**
Special conveyors.

**GARDNER, WM., AND SONS (GLOUCESTER), LTD.**
Powder plant mixers, sifters, grinders; elevators, conveyors.

**IBBETT ENGINEERING CO., LTD.**
Trailers, conveyors.

**INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.**

**I.T.D., LTD.**
Fork lift trucks, elevating platforms.

**KING, GEO. W., LTD.**
Equipment, conveyors, electric hoists, runways.

**LANGLEY, W., AND CO. (MECHANICAL HANDLING), LTD.**
Lift trucks; drum, carboy equipment.

**LEES, HENRY, AND CO., LTD.**

**MATHEW BROTHERS.**
Trucks to 8,000 lb, loading shovels.

**MORRIS, HERBERT, LTD.**
Conveyors, elevators, hoists, trucks.

**MOXEY, LTD.**
Conveyors, elevators.

**MELDRUM FLOOD-PAGE, LTD.**
Refuse; stokers.

**NEILL, WM., AND SON (ST. HELENS), LTD.**
Conveyors, screens.

**OMIC, LTD.**
Lift trucks, omicrates, pallet trucks.

**PARKER MITCHELL ENGINEERING CO., LTD.**
Special machinery; conveyors.

**PATERSON HUGHES ENGINEERING CO., LTD.**
Conveyors, elevators.

**POWER JACKS, LTD.**

**PRESSOTURN, LTD.**
Tote system.

**RELIANCE TRUCKS, LTD.**
Trucks, tractors, trailers.

**SERVICE ENGINEERING CO. (NORTHAMPTON), LTD.**
Conveyors, pallets, loading equipment.

**SHARPLES CENTRIFUGES, LTD.**
Liquid, dry powder classifiers.

**SHEEPBRIDGE EQUIPMENT, LTD.**

**SHELVOKE AND DREWRY, LTD.**
Fork lift trucks to 8 tons.

**SIMON, RICHARD, AND SONS, LTD.**
Automatic weighing, feeding, flaking machines.

**SMITH, JOHN A., LTD.**
Designers.

**SPENCER (MELKSHAM), LTD.**
Conveyors, elevators.

**STOTHERT AND PITT, LTD.**
Batching plants, concrete mixers.

**SUPERVENTS, LTD.**
Pneumatic conveying.

**TELEFLEX PRODUCTS, LTD.**
Materials, equipment.

**TEST EQUIPMENT, LTD.**

**TUBEWRIGHTS, LTD.**

**UNIVERSAL CONVEYOR CO., LTD.**

**THOMPSON, JOHN., LTD.**

**UNIVERSAL PATTERN AND PRECISION ENG. CO., LTD., THE.**
Equipment, special purpose.

**VICKERYS, LTD.**
Particle size classifiers.

**VICTOR ELECTRICS, LTD.**
Electric vehicles, trucks.

**WESSEX INDUSTRIES (POOLE), LTD.**
Trucks, fork; trailers, 20 tons.

**WEST'S GAS IMPROVEMENT CO., LTD.**
Conveyors.

**WICKHAM ENGINEERING CO., LTD.**
Conveyor, winches.

**WINGROVE AND ROGERS, LTD.**
Electric trucks.

**YALE AND TOWNE MANUFACTURING CO., THE.**
Lift trucks, to 200,000 lb; hoists.

## 202 MECHANICAL TEST EQUIPMENT

**AIRTECH, LTD.**
Strain gauges.

**ALLTOOLS, LTD.**
Load cells, 250 to 1,000,000 lb.

**ARMSTRONG WHITWORTH, SIR W. G., AIRCRAFT, LTD.**
Vibration equipment, wobbulators.

**AVERY, W. AND T., LTD.**
Machines; weighing, counting.

**BATY, J. E., AND CO., LTD.**
Micrometers, comparators, extensometers, profile projectors.

**BUTTERFIELD, W. P., LTD.**
Laboratories.

**BRITISH THOMSON-HOUSTON CO., LTD., THE.**
Dynamic balancing, frequency meters.

**CAMBRIDGE INSTRUMENT CO., LTD.**
Stress, strain, vibration, acceleration, extension.

**C.N.S. INSTRUMENTS, LTD.**
Extensometers.

**DAVISON AND CO. (HEXHAM), LTD.**
Creep machines; specials.

**DENISON, SAML., AND SON, LTD.**
Machines; weighing.

**ELECTRO-HYDRAULICS, LTD.**
Equipment.

**FALK, M., AND CO., LTD.**
High temperature creep, texture equipment.

**HAWKER SIDDELEY NUCLEAR POWER CO., LTD.**
Creep, stress corrosion, stability, high temp. facilities.

**H.L. INSTRUMENTS, LTD.**
Prototype, production; profile projector.

**JACKMAN, J. W., AND CO., LTD.**
Hardness testing machines.

**LUCAS, JOSEPH, LTD.**
Perspex models for gas dynamics studies.

**MARSTON EXCELSIOR, LTD.**
Bursting discs.

**MERLIN ENGINEERING CO., LTD.**
Fuel pump injection.

**M.H.H. ENGINEERING CO., LTD.**
Torquemeter, 3 lb in. to 1,500 lb ft.

**MOORES (BOURNEMOUTH), LTD.**
Porosimeters.

**PRINTED CIRCUITS, LTD.**
Strain gauges.

**RESEARCH AND CONTROL INSTRUMENTS, LTD.**
Roughness, strain, thickness, vibration; concrete deformation.

**SAUNDERS-ROE, LTD.**
Strain gauges; stress investigation service.

## 202 MECHANICAL TEST EQUIPMENT (contd.)

**SPEMBLY, LTD.**
Metallographic préparation apparatus.
**SPERRY GYROSCOPE CO., LTD.**
Non-destructive; thickness.
**STANHOPE-SETA, LTD.**
For petroleum, allied fields.
**TECHNOGRAPH ELECTRONIC PRODUCTS, LTD.**
Strain gauges.
**TELEGRAPH CONDENSER CO., LTD., THE.**
**TENSOMETER, LTD.**
Machines, equipment; testing irradiated materials.
**UNIVERSAL PATTERN AND PRECISION ENG. CO., LTD., THE.**
Test rigs, assemblies.
**VERNON INSTRUMENTS CO., LTD.**
Gauging, calibration.
**WYKEHAM, W., AND CO., LTD.**
Creep, universal tensile machines (A).

## 203 MERCURY

**ATKINSON, D. AND J. M., LTD.**
High-vacuum distilled.
**ENGELHARD INDUSTRIES, LTD. HANOVIA LAMPS DIVISION.**
"Autoset" vapour meters.
**HENDREY RELAYS, LTD.**
Vapour concentration meters.
**SCIENTIFIC METAL CO., LTD., THE.**

## 204 METAL FINISHING

**CANNING, W., AND CO., LTD.**
Electro-polishing.
**ELECTROPOL PROCESSING, LTD.**
Electrolytic polishing.
**ENGIS, LTD.**
Diamond compounds.
**METAL DIFFUSIONS, LTD.**
"Dicrom" metal diffusion; research.
**MINNESOTA MINING AND MANUFACTURING CO. LTD.,**
Coated abrasives.
**MORRIS, B. O., LTD.**
Polishing machinery.
**PITTER GAUGE AND TOOL CO., LTD.**
Precision lapping; alloys, graphite.
**RICHMOND INSTRUMENT CO., LTD.**
Optical polishing.
**STAINLESS EQUIPMENT CO. (METAL FINISHERS), LTD.**
Polishing, grinding; site services.
**VAN MOPPES, L. M., AND SONS (DIAMOND TOOLS), LTD.**
Diamond wheels, powders, tools.

## 205 METALS

*see also under individual headings*

**BERK, F. W., AND CO., LTD.**
Powders.
**BOLTON, THOMAS, AND SONS, LTD.**
High conductivity, copper base alloys; machined.
**BOOTH, JAMES, AND COMPANY, LTD.**
Non-ferrous, brass, copper, extrusions, sheet, plate, tube.
**BRAMAH, J. R., AND CO., LTD.**
Hafnium, niobium, tantalum, titanium.
**BROWN, JOHN, AND CO., LTD.**
Tungsten.
**CLIFFORD, CHARLES, LTD.**
Non-ferrous.
**COX AND DANKS, LTD.**
Suppliers.
**ENFIELD ROLLING MILLS, LTD.**
Copper, brass, zinc, phosphor, bronze.
**EXPANDED METAL CO., LTD., THE.**
Expanded steel, aluminium.
**FULMER RESEARCH INSTITUTE, LTD.**
Sponsored research development.
**GARDNER, HENRY, AND CO., LTD.**
Titanium, zirconium, indium, cadmium, bismuth, antimony (A).
**HARPER, JOHN, AND CO., LTD.**
Grey, meehanite, s.g. irons.
**HARVEY, G. A., AND CO., (LONDON), LTD.**
Perforated.
**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
Niobium, titanium.
**JESSOP, WM., AND SONS, LTD.**
Zirconium, titanium alloys.
**JOHNSON, MATTHEY AND CO., LTD.**
Rare earths, silver, platinum.
**LEAD WOOL CO., LTD., THE.**
Wools; steel, s.s., non-ferrous.
**LONDON METAL WAREHOUSES, LTD.**
Suppliers (A).
**LONDON AND SCANDINAVIAN METALLURGICAL CO., LTD.**
Chromium; ferro boron, niobium, manganese; molybdenum; alloy.
**MAGNESIUM ELEKTRON, LTD.**
Vanadium.
**MANGANESE BRONZE AND BRASS CO., LTD., THE.**
"Crotorite" aluminium bronze.
**METRO-CUTANIT, LTD.**
Vacuum melted; molybdenum sheet; sintered compounds.
**MINING AND CHEMICAL PRODUCTS, LTD.**
Bismuth, cadmium, indium; high purity.
**MUREX, LTD.**
Specials; tungsten, molybdenum, tantalum, niobium, zirconium.
**NEW METALS AND CHEMICALS, LTD.**
Cadmium; niobium; rare earths, nuclear grades; tantalum.
**ROLLET, H., AND CO., LTD.**
Sheet, rod, bar, section, tube, wire, strip.
**SAVILLE, J. J., AND CO., LTD.**
Zirconium, titanium alloys.
**SMITH, J., AND SONS (CLERKENWELL), LTD.**
Non-ferrous (A).
**TELEGRAPH CONSTRUCTIONS AND MAINTENANCE, THE.**
Magnetic, resistance, special.
**TITANIUM METAL AND ALLOYS, LTD.**
Titanium; bar, wire, sheet, foil, forgings.
**VACTITE WIRE CO., LTD.**
Molybdenum rods, wires, tapes.
**WALL COLMONOY (CANADA), LTD.**
Alloys, "Colmonoy" series; "Microbraz" brazing.
**YOUNG, A. S., AND CO., LTD.**
Hard facing; brazing (A); customer service.

## 206 MILLS

**BOULTON, WILLIAM, LTD.**
Fine grinding plant.
**MANN, ALBERT, ENGINEERING CO., LTD.**
Rolling, fuel element.
**MANSFIELD, FRANK, AND CO., LTD.**
Crushers.
**MARSHALL RICHARDS MACHINE CO., LTD.**
Rolling, swaging; drawbenches.
**MORITZ CHEMICAL ENGINEERING CO., LTD.**
Turbo; colloid grinding.
**NORTON, SIR JAMES FARMER, AND CO., LTD.**
Strip rolling, coilers, splitters.
**PODMORE, W., AND SONS, LTD.**
**PULVERIZING MACHINERY, LTD.**
Hammer, "Mikro" pulverizer.
**ROBERTSON, W. H. A., AND CO., LTD.**
Rolling; ferrous, non-ferrous metals.
**WILKINSON RUBBER LINATEX, LTD.**
Ball.

## 207 MOTORS, ELECTRIC

**ALLEN, W. H., SONS AND CO., LTD.**
One h.p. to 4,500 h.p.
**ANDEC, LTD.**
F.H.P.
**BROWNINGS ELECTRIC CO., LTD.**
Various; commutators, slip-rings.
**B.V.C. ELECTRONIC DEVELOPMENTS, LTD.**
Design, development, production.
**C.A.V., LTD.**
Low voltage.
**CROYDON ENGINEERING CO., LTD., THE.**
Various; rotary transformers, converters.
**DRAYTON REGULATOR AND INSTRUMENT CO., LTD.**
Geared units.
**ELECTRICAL POWER ENGINEERING CO., (B'HAM), LTD., THE.**
Flameproof.
**ELECTRO DYNAMIC CONSTRUCTION CO., LTD.,**
F.H.P., variable speed.
**ELECTROPOWER GEARS, LTD.**
Variable speed, geared.
**FRACTIONAL H.P. MOTORS, LTD.**
F.H.P.
**FROST, H., AND CO., LTD.**
F.H.P.
**FULLER ELECTRIC, LTD.**
**HARLAND ENGINEERING CO., LTD., THE.**
**HIGGS MOTORS, LTD.**
Geared specials.
**JONES AND STEVENS, LTD.**
F.H.P.
**JONES, WALTER, AND CO. (ENGINEERS), LTD.**
Synchronous, single, polyphase, induction; geared.
**KLAXON, LTD.**
F.H.P.; geared units.
**LAURENCE, SCOTT AND ELECTROMOTORS, LTD.**
Variable, constant speed, specials, frequency converters.
**LIMIT ENGINEERING GROUP, LTD.**
F.H.P., miniature.
**LUCAS, JOSEPH, LTD.**
**MATHER AND PLATT, LTD.**
**NELSON ENGINEERING CO., LTD., THE.**
**NEWMAN INDUSTRIES, LTD.**
A.C. induction, 1/6–600 h.p.
**OPPERMAN GEARS, LTD.**
Geared, spur, worm, helical.
**PELL, OLIVER, CONTROL, LTD.**
**PLESSEY CO., LTD., THE.**
24V.
**PULLIN, R. B., AND CO., LTD.**
Low voltage instrument.
**SMALL ELECTRIC MOTORS, LTD.**
Up to 10 h.p.
**SPERRY GYROSCOPE CO., LTD.**
Special purpose.
**VACTRIC (CONTROL EQUIPMENT), LTD.**
D.C. permanent magnet.

# N

## 208 NICKEL

**ALBRIGHT AND WILSON (MFG.), LTD.**
"Kanigen" plate.
**LANGLEY ALLOYS, LTD.**
Alloys, "Hastelloy" plate, sheet, tube, castings, forgings.
**LONDON AND SCANDINAVIAN METALLURGICAL CO., LTD.**
**MOND NICKEL CO., LTD., THE.**
**RHODES, B., AND SON, LTD.**
**WIGGIN, HENRY, AND CO., LTD.**
Corrosion resisting alloys; wrought, cast.

# O

## 209 OFFICE EQUIPMENT

**CONTOURA PHOTOCOPYING, LTD.**
**DARGUE BROTHERS, LTD.**
Drawing office equipment.
**EDISON, THOMAS A., LTD.**
Voicewriters, televoicewriters.
**HALDEN, J., AND CO., LTD.**
Drawing instruments; photo-copying.
**MASON, E. N., AND SONS, LTD.**
Copying equipment.
**MATTHEWS, D., AND SON, LTD.**
**PHOTOSTAT, LTD.**
Reproduction equipment.
**SWALLOW AND HICKS, LTD.**
Drawing office filing equipment.
**TAPE RECORDERS (ELECTRONICS), LTD.**
Tape recorders.
**THORNTON, A. G., LTD.**
**WELCONSTRUCT CO., LTD.**

## 210 OPTICAL EQUIPMENT

**AVIMO, LTD.**
Telescopes; lenses, grinding.
**CLARKSON, A., AND CO., LTD.**
Suppliers, repairers.
**COOKE, TROUGHTON AND SIMMS, LTD.**
Microscopes.
**COMBINED OPTICAL INDUSTRIES, LTD.**
Magnifiers, lenses.
**C.Z. SCIENTIFIC INSTRUMENTS, LTD.**
**DALLMEYER, J. H., LTD.**
Instruments, lenses, photography.
**DEGENHARDT AND CO., LTD.**
Agent.
**ELECTRONIC MACHINE CO., LTD.**
**FERRANTI, LTD.**
Diffraction, grating, measuring equipment.
**FOSTER INSTRUMENT CO., LTD.**
Instruments, introscopes, periscopes.
**GRUBB, SIR HOWARD, PARSONS AND CO., LTD.**
Periscopes.
**NEWBOLD AND BULFORD, LTD.**
Binoculars, telescopes, magnifiers, microscopes, projectors.
**O.P. INSTRUMENTS.**
Cinematographic specials.

## 210 OPTICAL EQUIPMENT (contd.)

**OPTICAL WORKS, LTD.**
For any degree of radiation.
**PATON HAWKSLEY.**
Diffraction gratings.
**ROSS, LTD.**
Instruments; binoculars, enlargers.
**SETON CREAGHE ENGINEERING CO., LTD.**
Defractometers.
**TAYLOR, TAYLOR AND HOBSON, LTD.**
Telescopes, lenses.
**TECHNE (CAMBRIDGE), LTD.**
Circle goniometer.
**TELECOMMUNICATION INSTRUMENTS, LTD.**
Diffraction microscope.
**WATSON, W., AND SONS, LTD.**
**WYKEHAM, W., AND CO., LTD.**
Instruments, electron microscopes, (A).

# P

## 211 PHOSPHORS

**EKCO ELECTRONICS, LTD.**
Sodium iodide.
**HILGER AND WATTS, LTD.**
**NASH AND THOMPSON, LTD.**
Organic, inorganic, plastic, liquid scintillators.
**NUCLEAR ENTERPRISES (G.B.), LTD.**
Plastic, gel, liquid; neutron; light pipes, chemicals; "Harshaw" crystals (A).
**TAYLOR, TAYLOR AND HOBSON, LTD.**

## 212 PIPES; Pipework
*see also TUBES*

**AITON AND CO., LTD.**
Carbon, alloy steel.
**ALLEN, ALFRED, AND SON, LTD.**
**ALLEN, W. G., AND SONS (TIPTON), LTD.**
Steel, alloy, s.s., aluminium; 10 tons.
**ASHMORE, BENSON, PEASE AND CO.**
**BABCOCK AND WILCOX, LTD.**
**BENTON AND STONE, LTD.**
Solderless fittings, nylon, copper.
**BRAMAH, J. R., AND CO., LTD.**
S.s.
**CHEMIDUS PLASTICS, LTD.**
Plastics.
**BRITISH APPLIANCES MFG. CO., LTD.**
**BROWN, JOHN, AND CO., LTD.**
**CARRUTHERS, J. H., AND CO., LTD.**
Separators.
**CHAMBERLAIN INDUSTRIES, LTD.**
Bending, rolling machines.
**CLARKE, CHAPMAN AND CO., LTD.**
**CLAY CROSS (IRON AND FOUNDRIES), LTD.**
Centrifugally spun, c.i. flanged.
**CLYDE TUBE FORGINGS, LTD.**
Seamless butt-welding, fittings, ferrous, non-ferrous.
**COLVIN-SMITH, LTD.**
Fabrication, erection, ferrous, non-ferrous.
**CRANE PACKING, LTD.**
Joints; plastics.
**CUPROCYL, LTD.**
**DARHAM INDUSTRIES (LONDON), LTD.**
**DAVEY, PAXMAN AND CO., LTD.**
Fabrication, tube manipulation.
**DIXON-BATE, B., LTD.**
Flanges.
**ENGINEERING SERVICE INSTALLATIONS, LTD.**
Prefabricated; erection; heating, ventilating, electrical, sanitary.
**FINDLAY, ALEX., AND CO., LTD.**
Steel.
**FIRTH BLAKELEY SONS AND CO., LTD.**
Steel, 15 in. dia. upwards.
**HARVEY, G. A., AND CO. (LONDON), LTD.**
Flanges, ends, rings.
**HILMOR, LTD.**
Bending machines; ferrous, non-ferrous.
**HORSELEY BRIDGE AND THOMAS PIGGOTT, LTD.**
Fabricated; specials.
**HOWELL AND CO., LTD.**
**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
**INTERNATION COMBUSTION (NUCLEAR APPLICATIONS), LTD.**
Fabrications, tube manipulation.
**JENKINSON, W. G., LTD.**
S.s., aluminium.
**JOHNSTONE, ARCHIBALD, (ENGINEERS), LTD.**
**KIRK AND COMPANY (TUBES), LTD.**
Fabrication, erection; steel, s.s.
**LAWRIE, J. AND T., LTD.**
Design, fabrication, erection; fittings, steel, non-ferrous.
**LONGCLOSE ENGINEERING CO., LTD.**
S.s.
**LUCAS, JOSEPH, LTD.**
S.s., nimonics, titanium.
**MACLELLAN, P. AND W., (PULLIN), LTD.**
Large diameter, welded, pressure.
**MARSTON EXCELSIOR, LTD.**
Light alloy.
**MENDIP (CHEMICAL ENGINEERING), LTD.**
Condensers; chemical systems; reinforced resin.
**MUNRO AND MILLER, LTD.**
Fabrication, erection.
**OIL FEED ENGINEERING CO., LTD.**
Hydraulic; flexible assemblies; "Hi-Flex," hose.
**OXLEY, WM., AND CO., LTD.**
Flanges, s.s.
**PALMER AERO PRODUCTS, LTD.**
Flexible, rigid.
**PAYTER, E. C., AND CO., LTD.**
Lines, fittings, to 36 in. dia.; Al alloy.
**PEARSON, T. B., AND SONS, LTD.**
**PIPE FABRICATORS (STAMFORD), LTD.**
Steel, seam welded to $\frac{1}{2}$ in. thick; fittings.
**PIPEWELD, LTD.**
Jacketed; site erection.
**PIPEWORK AND ENGINEERING (BRISTOL), LTD.**
S.s., steels, non-ferrous alloys.
**PRESS, WILLIAM, AND SON, LTD.**
Systems design; fabrication to 18 in. dia.
**PULVERIZING MACHINERY, LTD.**
S.s., copper, mild steel, glass lined.
**REDHEUGH IRON AND STEEL (1936), LTD.**
**RESISTANT EQUIPMENT, LTD.**
**RICHARDSON, W., AND CO., LTD.**
To 6 ft dia., $\frac{1}{4}$ in. plate.
**RICHARDSONS, WESTGARTH AND CO., LTD.**
**ROTHERHAM AND SONS, LTD.**
Fittings, unions.
**SHAW GLASGOW, LTD.**
C.I. flanged fittings.
**SHAW AND McINNES, LTD.**
Contractors.
**SHAW-PETRIE, LTD.**
**SMEATON AND SONS, LTD.**
Design, installation.
**SMITH, JOHN A., LTD.**
Engineering design; contractors.
**STEAM AND COMBUSTION ENGINEERING, LTD.**
**SOUTH DURHAM STEEL AND IRON CO., LTD.**
Steel welded.
**SPIRO-GILLS, LTD.**
**SPUN CONCRETE, LTD.**
Concrete, tunnel linings.
**STANTON IRONWORKS CO., LTD., THE.**
Spun iron.
**STAVELEY IRON AND CHEMICAL CO., LTD., THE.**
"Stavoxy" epoxy resin-lined c.i.
**STEELS ENGINEERING INSTALLATIONS, LTD.**
Fabrication; tube manipulation.
**STEWARTS AND LLOYDS, LTD.**
Contractors; fittings; gas, steam, water, fabrication.
**STOCKDALE ENGINEERING, LTD.**
S.s. acid resisting.
**TANKS AND LININGS, LTD.**
Acid resisting plastic.
**TERRASPAN, LTD.**
Flanges, mantonflange, s.s., chemical plant.
**THOMPSON, JOHN, LTD.**
Fabrication, erection.
**TUBELA ENGINEERING CO., LTD.**
Bending; hand, hydraulic.
**UNIT SUPERHEATER AND PIPE CO., LTD., THE.**
High quality.
**UNIVERSAL BOILERS AND ENGINEERING CO., LTD.**
**VICKERS-ARMSTRONGS (ENGINEERS), LTD.**
**WALKER, C. AND W., LTD.**
Flanges, supports.
**WARD, THOS. W., LTD.**
S.s., m.s., copper, etc.; installation.
**WATSON, ROBT., AND CO. (CONSTRUCTIONAL ENGINEERS), LTD.**
Large dia.
**WELDING TECHNICAL SERVICES, LTD.**
Standard parts, s.s., alloys, to 8 in. bore.
**WELLINGTON TUBE WORKS, LTD.**
Fabricated, flanged.
**WIDNES WELDING CO.**
**WILSON PIPE FITTINGS, LTD.**
"Weldolets" fittings; carbon, alloy, s.s., c.i.
**WRIGHT ANDERSON AND CO., LTD.**
Lines, welded.
**X-LON PRODUCTS.**
Plastics.
**YORKSHIRE ENGINEERING AND WELDING CO. (BRADFORD), LTD.**

## 213 PIPE SUPPORTS

**AITON AND CO., LTD.**
Constant load.
**BRITISH INDUSTRIAL ENGINEERING CO., LTD.**
Constant, variable tension; spring.
**CON-TEN CO., THE.**
Constant tension.
**MADAN, CHARLES S., AND CO., LTD.**
Strainers.
**VOKES GENSPRING, LTD.**
Constant, variable hangers, sway braces.

## 214 PLASTICS

**ALBRIGHT AND WILSON (MFG.), LTD.**
"Hetron" flame-resistant polyester resins.
**AUTO AERO, LTD.**
Profile shapes, shims, gaskets.
**BELCLERE CO., THE.**
Mouldings, encapsulated electronic circuits.
**BIP CHEMICALS, LTD.**
Moulding powders, resins, advisory service.
**BRITISH ROPES, LTD.**
Nylon, terylene ropes; nets; slings; cloths.
**BURY FELT MANUFACTURING CO., LTD., THE.**
"Foambury," plastic foam.
**BX PLASTICS, LTD.**
"Cobex," styrafoil, triacetate film, bextrene sheeting.
**CHEMICAL PIPE AND VESSEL CO., LTD.**
Polythene, PVC, PTFE, tubes, mouldings, linings.
**CHEMIDUS PLASTICS, LTD.**
Solid bar to 4 in.
**CIBA (A.R.L.), LTD.**
"Araldite" epoxy resins.
**COMBINED OPTICAL INDUSTRIES, LTD.**
Mouldings.
**COOPER AND CO. (BIRMINGHAM), LTD.**
Polyurethane flexible foam.
**CORNERCROFT, LTD.**
Moulds, mouldings.
**FAIREY AVIATION CO., LTD., THE.**
Injection moulding.
**FIBRECLAD, LTD.**
Mouldings.
**GIRDLESTONE PUMPS, LTD.**
Polythene mouldings.
**GOSHERON, JOHN, AND CO., LTD.**
Self-adhesive tapes.
**HELLERMAN, LTD.**
Extrusion moulding.
**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
"Alkathene"; "Maranyl" nylon.
**INSULATING COMPONENTS AND MATERIALS, LTD.**
Electrical components, precision machining, mouldings.
**IOCO, LTD.**
"Formapex" laminated.
**KITSON'S INSULATIONS, LTD.**
Expanded polystyrene.
**LITHOLITE INSULATORS AND ST. ALBANS MOULDINGS, LTD.**
Mouldings.
**MANGE PLASTICS, LTD.**
Tubing; irradiated.
**MARINE AND INDUSTRIAL PLASTICS, LTD.**
Fabrications, ducts, tubes.
**METROPOLITAN PLASTICS, LTD.**
Trade mouldings.
**MICROCELL ELECTRONICS.**
Laminates, mouldings.
**MINERVA LABORATORIES (INSTRUMENTS), LTD.**
Specialized components.
**MORANE PLASTIC CO., LTD.**
"Morane" heatsealing; large-scale laminations.
**NATIONAL PLASTICS (SALES), LTD.**
Special moulded components.
**OPENSHAW, WILLIAM, LTD.**
Linings, coverings, fabrications.
**PERMALI, LTD.**
PTFE processed.
**PLASTICABLE, LTD.**
PVC sleeving.
**POLYPENCO, LTD.**
Nylon, PTFE extruded shapes; fabricated parts.
**RAY ENGINEERING CO., LTD., THE.**
"Rencol" handwheels.
**RESISTANT EQUIPMENT, LTD.**
Polythene, PVC, sheet, rod, mouldings, tubing.
**ROBERTS, J. W., LTD.**
Asbestos reinforced, glass reinforced.
**ROLLET, H., AND CO., LTD.**
Sheet, rod, tube, etc.; nylon.
**RUBBER IMPROVEMENT, LTD.**
PVC sheetings.
**SHELL CHEMICAL CO., LTD.**
"Epikote" epoxy resins.
**SPESCO DEVELOPMENTS, LTD.**
Polythene bag printers.

## 214 PLASTICS (contd.)

**STEEL, J. M., AND CO., LTD.**
Polyester, epoxy resins.
**TELEGRAPH CONSTRUCTION AND MAINTENANCE CO., LTD., THE.**
Powder, tubing, mouldings, laminations.
**THERMO PLASTICS, LTD.**
Mouldings, sheets; fabrication; glass-reinforced.
**UNIVERSAL METAL PRODUCTS, LTD.**
Mouldings, extrusion; glass-fibre-reinforced.
**WEYMOUTH RADIO MANUFACTURING CO., LTD.**
Encapsulation.
**WHITELEY ELECTRICAL RADIO CO., LTD.**
Circuit encapsulation.

## 215 PROTECTIVE CLOTHING

**BARBOUR, J., AND SONS, LTD.**
All forms; PVC, oiled-cotton, etc.
**BELL'S ASBESTOS AND ENGINEERING, LTD.**
**BIRMINGHAM PROTECTIVE CLOTHING CO., THE.**
Gloves, overalls, aprons.
**CHICHESTER RUBBER CO., LTD., THE.**
Gloves; rubber, latex.
**CITY UNIFORM MANUFACTURING CO., THE.**
**COMPTON, J., SONS AND WESS, LTD.**
Donkey jackets.
**EASTWOOD PLASTICS, LTD.**
Oversuits.
**FLEMING, J. AND R., LTD.**
Eye, face shields.
**FRANKENSTEIN, P., AND SONS (MANCHESTER), LTD.**
Suits.
**MELLOWHIDE PRODUCTS, LTD.**
PVC coated fabrics.
**JESSEMAN, LEONARD J., LTD.**
**NORTH, JAMES, AND SONS, LTD.**
PVC coated garments; gloves.
**NORTHIDE, LTD.**
North PVC distributor.
**PLYSU PRODUCTS, LTD.**
Unsupported PVC; pressure ventilated.
**PROTECTIVE FOOTWEAR SERVICE, LTD.**
Footwear.
**SAFETY PRODUCTS, LTD.**
"Pulsafe" industrial safety equipment.
**SIEBE, GORMAN AND CO., LTD.**
Respirators, harnesses, telephones, specials.
**SPEMBLY, LTD.**
Pressure ventilated; air supply equipment.
**STENHOUSE EQUIPMENT, CO.**
Gloves, goggles, respirators.
**TEDSON, THORNLEY, AND CO., LTD.**
Leather, asbestos, cotton, PVC gloves.
**TIMEG, LTD.**
Neoprene footwear, headgear, gloves, clothing.
**VARLEY, JAMES, AND CO., LTD.**
Overalls, industrial.
**VEEDIP, LTD.**
Gloves, gauntlets.

## 216 PULSE HEIGHT ANALYSERS

**DYNATRON RADIO, LTD.**
**ISOTOPE DEVELOPMENTS, LTD.**
Single channel.
**MULLARD EQUIPMENT, LTD.**
100-channels.
**NUCLEAR ENTERPRISES (G.B.), LTD.**
Single channel, 100-channel; transistorised.
**SUNVIC CONTROLS, LTD.**
Multichannel.

## 217 PUMPS

**AIR PUMPS, LTD.**
Vacuum, rotary, reciprocating.
**ALLEN, W. H., SONS AND CO., LTD.**
Circulating, water main, auxiliary.
**ALLEY AND MACLELLAN (PLOMADIE), LTD.**
Vacuum.
**APPLETON AND HOWARD, LTD.**
For chemical corrosive liquids.
**AUTOMETRIC PUMPS, LTD.**
Centrifugal, turbine, piston, vacuum, gear, diaphragm.
**BAILEY, SIR W. H., AND CO., LTD.**
Pressure.
**B.E.N. PATENTS, LTD.**
Vacuum.
**BOVING AND CO., LTD.**
Turbine, water.
**BRITISH LABOUR PUMP CO., LTD.**
Self-priming, glandless.
**BROWN, DAVID, CORPORATION (SALES), LTD., THE.**
"Roloid."
**BROWN, DAVID, INDUSTRIES, LTD.**
**BRACKETT, F. W., AND CO., LTD.**
Slurry, diaphragm, air, water, vacuum.
**BRITISH PLEUGER SUBMERSIBLE PUMPS, LTD.**
Submersible motor, sump, borehole, propeller.
**CLARKE, CHAPMAN AND CO., LTD.**
**CROWN PUMP MANUFACTURING CO., LTD.**
Rotary gear, centrifugal, submersible, ancillaries.
**C.T. (LONDON), LTD.**
Glandless.
**DAWSON AND DOWNIE, LTD.**
**DISTILLERS CO., LTD., THE.**
Diaphragm, metering, plunger.
**DRYSDALE AND CO., LTD.**
Large capacity centrifugal.
**E.C.D., LTD.**
Precision, metering, proportioning; liquids, gases.
**EDWARDS HIGH VACUUM, LTD.**
High vacuum, rotary, diffusion, booster, vapour.
**EVANS, JOSEPH, AND SONS (WITON), LTD.**
Positive displacement.
**FLEISCHMANN (LONDON), LTD.**
Fore, Roots, diffusion.
**FRASER, ANDREW, AND CO., LTD.**
Hydraulic.
**FRIEDENTHALS, LTD.**
Reciprocating, steam.
**GENERAL ENGINEERING (RADCLIFFE), LTD.**
"Kinney" high vacuum, booster, viscous fluid.
**GENEVAC, LTD.**
Rotary diffusion, booster, high vacuum.
**GILKES, GILBERT, AND GORDON, LTD.**
Self-priming, centrifugal, multi-stage, circulating.
**GODFREY, SIR GEORGE, AND PARTNERS (INDUSTRIAL), LTD.**
Vacuum.
**GOODWIN, ARNOLD, LTD.**
Vacuum; hand, power operated.
**GWYNNES PUMPS, LTD.**
Centrifugal, mixed flow, axial flow.
**HALL ENGINEERING, LTD.**
Special.
**HARLAND ENGINEERING CO., LTD., THE.**
Centrifugal.
**HAYWARD TYLER AND CO., LTD.**
Zero leakage, glandless, submersible, research facilities.
**HICK HARGREAVES AND CO., LTD.**
Rotary
**HOWARD MECHANICAL DEVELOPMENTS, LTD.**
Glandless.
**HOWARD PNEUMATIC ENGINEERING CO., LTD., THE.**
Rotary, centrifugal, triplex, proportiometer.
**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
Diffusion pump fluids.
**INGERSOLL-RAND CO., LTD.**
Vacuum.
**INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.**
**JENCONS (SCIENTIFIC), LTD.**
Mercury vapour.
**KINGSBOURNE PRODUCTS, LTD.**
Pneumatic.
**KONTAK MANUFACTURING CO., LTD.**
Glandless, positive displacement, metering.
**KSB MANUFACTURING CO., LTD.**
Boiler-feed, glandless, vacuum, process, submersible.
**LACY-HUBERT AND CO., LTD.**
Vacuum, reciprocating, non-lubricated rotary.
**THOM, LAMONT AND CO., LTD.**
Steam, electric reciprocating.
**LEE, HOWL AND CO., LTD.**
Pumping machinery.
**LEYBOLD VACUUM SALES, LTD.**
High vacuum (A).
**LONGCLOSE ENGINEERING CO., LTD.**
S.s. centrifugal.
**MATHER AND PLATT, LTD.**
Centrifugal.
**MERRILL PUMPS, LTD.**
Glandless, self-priming, diaphragm, straight-way multiport.
**METERING PUMPS, LTD.**
Variable stroke, metering.
**MITCHELL, L. A., LTD.**
Acid.
**MONO PUMPS, LTD.**
Rotary, positive-acting, self-priming.
**NEWBURGH ENGINEERING CO., LTD.**
**N.G.N. ELECTRICAL, LTD.**
Rotary vacuum, oil diffusion; low temperature trap degassing units.
**NORTHEY ROTARY COMPRESSORS, LTD.**
Vacuum, diffusion.
**PALATINE TOOL AND ENGINEERING CO. (SURBITON), LTD.**
Electro-magnetic.
**PLENTY AND SON, LTD.**
High pressure feed.
**PULLEN, FREDERICK A., AND CO., LTD.**
Centrifugal, reciprocating.
**PULSOMETER ENGINEERING CO., LTD., THE.**
Centrifugal, special duty; high vacuum.
**RANSOMES AND RAPIER, LTD.**
Self-priming.
**REAVELL AND CO., LTD.**
Vacuum.
**ROTHERHAM AND SONS, LTD.**
**SAUNDERS VALVE CO., LTD.**
Centrifugal.
**SAVERY, THOMAS, PUMPS, LTD.**
Small capacity, annular piston.
**SCREW MACHINE PRODUCTS, LTD.**
Units.
**SIGMUND PUMPS, LTD.**
Centrifugal.
**SLACK AND PARR, LTD.**
Metering pumps, components.
**SPE COMPANY, LTD.**
Fuel.
**STANHOPE ENGINEERS (BRADFORD), LTD.**
"Shackleton" suds; "Stanwin" rotary gear.
**STOTHERT AND PITT, LTD.**
Screw, rotary, displacement, V.S., rotary centrifugal.
**SULZER BROS. (LONDON), LTD.**
**TANGYES, LTD.**
Centrifugal, reciprocating.
**THOMAS AND SON (WORCESTER), LTD.**
Reciprocating machinery.
**TOWLER BROS. (PATENTS), LTD.**
High speed, oil, high pressure.
**TUBELA ENGINEERING CO., LTD.**
Units.
**URQUHARTS (1926), LTD.**
Volumetric metering.
**VACUUM INDUSTRIAL APPLICATIONS, LTD.**
Oil diffusion, rotary vacuum, booster.
**VACUUM RESEARCH (CAMBRIDGE), LTD.**
Booster; glycerine, mercury vapour, oil diffusion.
**VARLEY-FMC, LTD.**
Gear; turbine.
**VICKERS-ARMSTRONGS (ENGINEERS), LTD.**
Large capacity cooling water.
**V.M.D., LTD.**
Vacuum, rotary-vane, Roots, diffusion.
**WALLWIN (PUMPS), LTD.**
Unchokeable, semi-unchokeable, centrifugal, submersible.
**WEIR, G. AND J., LTD.**
Boiler circulating, glandless.
**WICKHAM ENGINEERING CO., LTD.**
Sludge.
**WILKINSON RUBBER LINATEX, LTD.**
"Linatex" rubber-lined centrifugal, diaphragm.
**WILSON, ALEXANDER (ABERDEEN), LTD.**
Vacuum.
**WORTHINGTON-SIMPSON, LTD.**
All types.

## 218 PURIFICATION PLANT

**BRITISH OXYGEN ENGINEERING, LTD.**
Gas.
**CONSTRUCTIONAL ENGINEERING CO., LTD., THE.**
Gas washing.
**ENGELHARD INDUSTRIES, LTD.**
Gas.
**HEAD WRIGHTSON PROCESSES, LTD.**
**METAFILTRATION CO., LTD.**
Transformer oils.
**PATERSON ENGINEERING CO., LTD., THE.**
Filtration; clarifiers, ion exchange, chlorinators, softening.
**WALKER, C. AND W., LTD.**
Gas cleaning.
**WESTERN DETAIL MANUFACTURERS, LTD.**
Argon gas.

# R

## 219 RADIATION MEASUREMENT

*see also G-M TUBES, SCINTILLATION COUNTERS, HEALTH MONITORS, SURVEY EQUIPMENT*

**AIRMEC, LTD.**
**AVIMO, LTD.**
Ionization chambers, beta gamma probe units.
**AVO, LTD.**
Portable d.c. amplifier, ion chambers, scalers.
**BALDWIN INSTRUMENT CO., LTD.**
Ionization chambers.
**B. AND K. LABORATORIES, LTD.**
(A) Nuclear Chicago Corporation, U.S.A.

## 219 RADIATION MEASUREMENT (contd.)

**BRITISH PHYSICAL LABORATORIES.**
Linear amplifiers.
**BURNDEPT, LTD.**
Ratemeters; alphs, beta, gamma, fast neutron counters.
**CINEMA-TELEVISION, LTD.**
Automatic counting equipment; EHT units.
**DYNATRON RADIO, LTD.**
Amplifiers, scalers, probes.
**EKCO ELECTRONICS, LTD.**
Ratemeters, scalers, electrometers, G-M equipment.
**ERICSSON TELEPHONES, LTD.**
Amplifiers; EHT, quench, units, electrometers, ratemeters, scalers.
**FALK, M., AND CO., LTD.**
Instruments (A).
**FLEMING RADIO (DEVELOPMENTS), LTD.**
Ratemeters.
**GENERAL RADIOLOGICAL, LTD.**
Ratemeters, scalers, pulse amplifiers, ion chambers.
**HALL ENGINEERING, LTD.**
Ion chamber equipment.
**HAWNT AND CO., LTD.**
Laboratory instruments, accessories (A).
**ILFORD, LTD.**
Photographic emulsions.
**ISOTOPE DEVELOPMENTS, LTD.**
Scalers, amplifiers, ratemeters, EHT units.
**LABGEAR, LTD.**
Range for research, medicine, industry.
**MULLARD, LTD.**
Detectors, G-M tubes.
**NUCLEAR ENTERPRISES (G.B.), LTD.**
Amplifiers, pre-amplifiers, EHT units; C-14, tritium assemblies.
**NUCLEAR RESEARCH APPLICATIONS, LTD.**
Laboratory instruments.
**OPTICAL WORKS, LTD.**
Cerenkov blocks.
**P.A.M., LTD.**
R.F. EHT units to 12 kV d.c.
**PANAX EQUIPMENT, LTD.**
Castles; scalers, automatic; ratemeters; power units.
**PLESSEY NUCLEONICS, LTD.**
Ion chambers; fission counters; flux scanning, measuring.
**RADIATION MONITORS, LTD.**
" Utility " geiger counter.
**RESEARCH AND CONTROL INSTRUMENTS, LTD.**
Ratemeters, scalers, G-M counters, EHT units, castles.
**SARGROVE ELECTRONICS, LTD.**
Instrument development service.
**STONEBRIDGE ELECTRICAL CO., LTD., THE.**
Equipment (A).
**SUNVIC CONTROLS, LTD.**
Flux, radiation.
**TOWERS, J. W., AND CO., LTD.**
Monitors, detectors, planchets.
**VACUUM INDUSTRIAL APPLICATIONS, LTD.**
Ionization chambers, Alpharay gauge units.
**20TH CENTURY ELECTRONICS, LTD.**
Ion, fission chambers; G–M tubes.

## 220 RADIOGRAPHY

**FALK, M., AND CO., LTD.**
Gamma equipment.
**GAMMA-RAYS, LTD.**
Gamma-ray; pipeline, pressure vessel inspection.
**GAMMAX, LTD.**
Handling equipment; testing; inspection service.
**INDUSTRIAL RADIOGRAPHY (NDT), LTD.**
X-ray; on-site.
**KODAK, LTD.**
X-ray films.
**LONDON ALUMINIUM CO., LTD., THE.**
Vacuum testing.
**MARCONI INSTRUMENTS, LTD.**
Industrial X-ray.
**MOTHERWELL BRIDGE AND ENGINEERING CO., LTD., THE.**
Services on world-wide basis.
**NUCLEAR ENGINEERING, LTD.**
Gamma-source transport, storage containers.
**PALMER AERO PRODUCTS, LTD.**
X-ray.
**PANTAR, LTD.**
X-ray equipment.
**SOLUS-SCHALL, LTD.**
Industrial X-ray, gamma.
**UNIT SUPERHEATER AND PIPE CO., LTD., THE.**
Lloyd's approved.
**WATSON AND SONS (ELECTRO-MEDICAL), LTD.**
X-ray apparatus.
**WELDING SUPPLIES, LTD.**
X-ray.

## 221 REACTORS, NUCLEAR

**A.E.I.-JOHN THOMPSON NUCLEAR ENERGY CO., LTD.**
Base-load power stations; "Merlin" research.
**ATOMIC POWER CONSTRUCTION, LTD.**
Base-load power stations.
**BABCOCK AND WILCOX, LTD.**
Gas-cooled, water-cooled.
**B. AND K. LABORATORIES, LTD.**
Student type, sub-critical (A).
**ENGLISH ELECTRIC CO., LTD., THE.**
Base-load power stations.
**GENERAL ELECTRIC CO., LTD., THE.**
Base-load power stations.
**HAWKER SIDDELEY NUCLEAR POWER CO., LTD.**
Research; " Jason."
**HEAD WRIGHTSON PROCESSES, LTD.**
Heavy water materials testing.
**HIVOLT, MILES, LTD.**
Sub-critical assemblies (A).
**HUMPHREYS AND GLASGOW, LTD.**
PWR; Alco Products, Ltd. collaborators.
**MITCHELL ENGINEERING, LTD.**
PBWR, with A.M.F. Atomics, G.N.E.C.
**NUCLEAR POWER PLANT CO., LTD., THE.**
Base-load power stations.
**ROLLS-ROYCE, LTD.**
Nuclear propulsion systems.
**VICKERS-ARMSTRONGS (ENGINEERS), LTD.**
Materials-testing, LIDO type.
**VICKERS NUCLEAR ENGINEERING, LTD.**

## 222 RECORDERS

**ARMSTRONG, SIR W. G., WHITWORTH AIRCRAFT, LTD.**
Multi-point, pressure transient.
**BAILEY METERS AND CONTROLS, LTD.**
**BOULTON PAUL AIRCRAFT, LTD.**
Multi-channel oscillographs.
**BRITISH ROTOTHERM CO., LTD., THE.**
Pressure, temperature, thermostats.
**CAMBRIDGE INSTRUMENT CO., LTD.**
**C.N.S. INSTRUMENTS, LTD.**
Printing microvoltmeter; extensometer to 300°C.
**DEVON INSTRUMENTS, LTD.**
Chart motors.
**DOBBIE MCINNES (ELECTRONICS), LTD.**
" Sefram."
**ELLIOTT NUCLEONICS, LTD.**
**EVERSHED AND VIGNOLES, LTD.**
**FIELDEN ELECTRONICS, LTD.**
Level, temperature, pressure, flow.
**FOSTER INSTRUMENT CO., LTD.**
Temperature indicators, controllers.
**GENT AND CO., LTD.**
**GLEDHILL-BROOK TIME RECORDERS, LTD., THE.**
Equipment, time.
**HENDREY RELAYS, LTD.**
Single channel.
**HONEYWELL CONTROLS, LTD.**
Flux, power, period, flow, pressure, temperature.
**INTEGRA, LEEDS AND NORTHRUP, LTD.**
**KELVIN AND HUGHES (INDUSTRIAL), LTD.**
High frequency.
**KENT, GEORGE, LTD.**
Flow, pressure, temperature, power level, radiation, flux.
**LEA RECORDER CO., LTD., THE.**
Flow, level; trade effluent.
**NALDER BROS. AND THOMPSON, LTD.**
**RECORD ELECTRICAL CO., LTD., THE.**
**RESEARCH AND CONTROL INSTRUMENTS, LTD.**
" Oscilloscript," temperature, flow, conductivity pressure, level.
**ROBINSON, F. C., AND PARTNERS, LTD.**
Multi, single pen.
**SENSITISED COATINGS, LTD.**
Recorder accessories.
**SERVIS RECORDERS, LTD.**
Time.
**SHANDON SCIENTIFIC CO., LTD.**
Microvoltmeter, pressure, gas density, vibration (A).
**SUNVIC CONTROLS, LTD.**
Potentiometric.
**SMITH, SYDNEY, AND SONS (NOTTINGHAM), LTD.**
**TEST EQUIPMENT, LTD.**
**THOMPSON, JOHN, INSTRUMENT CO., LTD.**
Pressure, temperature.
**ZEAL, G. H., LTD.**

## 223 REFRIGERATION PLANT

**BROTHERHOOD, PETER, LTD.**
**CROWTHORN ENGINEERING CO., LTD., THE.**
**HEAT TRANSFER, LTD.**
**IMPERIAL CHEMICAL INDUSTRIES, LTD.**
" Arcton " refrigerants.
**LIGHTFOOT REFRIGERATION CO., LTD., THE.**
Frecon, ammonia.
**METROPOLITAN REFRIGERATION, LTD.**
Bulk $CO_2$; storage (A).
**PORTER, ALFRED, AND CO., LTD.**
**STERNE, L., AND CO., LTD.**
In all sizes.
**UNITED AIR COIL, LTD.**
**WEATHERFOIL HEATING SYSTEMS, LTD.**
**WESTERN DETAIL MANUFACTURERS, LTD.**
Vacuum line cold trap supplies.
**YORK SHIPLEY, LTD.**

## 224 REMOTE HANDLING

*see also WINDOWS*

**ALLEN, P. W., AND CO.**
Periscopes, telescopic systems, lighting.
**ARMSTRONG, SIR W. G., WHITWORTH AIRCRAFT, LTD.**
Equipment.
**AYLING NUCLEAR EQUIPMENT CO.**
Glove boxes.
**BERK, F. W., AND CO., LTD.**
Zinc bromide solution.
**B.M.B. (SALES), LTD.**
Vacuum cabinets.
**BRITISH PAINTS, LTD.**
" B.P.L." strippable paint.
**BROWN, E. G., AND CO., LTD.**
Glove boxes.
**CHICHESTER RUBBER CO., LTD., THE.**
Dry box rubber gauntlets.
**EASTWOOD PLASTICS, LTD.**
Plastic glove-box bags, sleeves, tong gaiters.
**EVANS, J., AND SON (PORTSMOUTH), LTD.**
Power assisted, manual tonging.
**FLEETLANDS, LTD.**
Glove boxes, shielding windows.
**GENERAL ELECTRIC CO., LTD., THE.**
Master slave manipulators.
**GENERAL RADIOLOGICAL, LTD.**
Dry boxes (A).
**GREY AND MARTEN, LTD.**
Lead spheres, bungs; mirror, aperture units.
**GRUBB, SIR HOWARD, PARSONS AND CO., LTD.**
Periscope viewing systems.
**HALL ENGINEERING, LTD.**
Dry boxes.
**H.L. INSTRUMENTS, LTD.**
Tongs, head assemblies, dry boxes, fittings.
**HOBSON, H. M., LTD.**
Master slave manipulators (Mode' 7).
**HULL, F., AND SONS, LTD.**
Manipulators.
**INTERNATIONAL ENGINEERING CONCESSIONAIRES, LTD.**
Dry boxes.
**IRWIN, E. G., AND PARTNERS, LTD.**
In-pile rigs; caves, shielded lines.
**LEYBOLD VACUUM SALES, LTD.**
Manipulators (A).
**LUCAS, JOSEPH, LTD.**
Design, fabrication capacity.
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Glove boxes, plastics; shielding windows.
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Lead glass windows, viewing periscopes, liquid windows.
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Dry boxes, manipulators.
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Manipulators; special machines; closed circuit T.V.
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Tools, specials; master slave manipulators.
**SCREW MACHINE PRODUCTS, LTD.**
Equipment, components, assemblies.
**SEALEY ENGINEERING CO., LTD.**
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**SETON CREAGHE ENGINEERING CO., LTD.**
**SPEMBLY, LTD.**
**TELEFLEX PRODUCTS, LTD.**
Manipulators.
**TOWERS, J. W., AND CO., LTD.**
Glove boxes, lead bricks, castles.
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Glove cabinets rigid, flexible, handling tongs.
**UNIBRIX RADIATION SHIELDINGS, LTD.**
Accessories, lead glass windows.
**WESTERN DETAIL MANUFACTURERS, LTD.**
Tongs, manipulators, glove boxes.
**WILSON, A. C., AND PARTNERS, LTD.**
Power manipulators, glove boxes, tongs, windows.

## 225 RUBBER GOODS

ANDRE RUBBER CO., LTD., THE.
Metal bonded components, anti-vibration mountings.
ANGUS, GEORGE, AND CO., LTD.
Mouldings.
A.V.A., LTD.
Moulded, metal bonded, mountings.
AVICA EQUIPMENT, LTD.
Synthetic, flexible hose assemblies.
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High pressure hoses.
BULL, JOHN, RUBBER CO., LTD.
Moulding, convoluted hose.
CHILLCOTTS, LTD.
Synthetic, extrusions, mouldings.
DENTON AND CO.
Mechanical rubbers, plastic components.
EMPIRE RUBBER CO.
Mouldings, sponge, metal bonded.
FIRESTONE TYRE AND RUBBER CO., LTD.
Rubber-to-metal bonded parts.
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Natural, synthetic; sheetings, mouldings, extrusions.
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Bonded to metal components.
NORTHERN RUBBER CO., LTD., THE.
Synthetic; to meet specific requirements.
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Compounding, moulding, extruding, expanded, foam.
PROTECTIVE RUBBER COATINGS (BRISTOL), LTD.
Coatings.
SOUND INDUSTRIES.
Moulded seals.
ST. HELENS CABLE AND RUBBER CO., LTD.
Mouldings.
WHITBY AND CHANDLER, LTD.
Fabrication.

# S

## 226 SCINTILLATION COUNTERS

*see also PHOSPHORS*

B. AND K. LABORATORIES, LTD.
(A) Nuclear Chicago Corporation, U.S.A.
EKCO ELECTRONICS, LTD.
E.M.I. ELECTRONICS, LTD.
Photomultiplier tubes.
INDUSTRIAL RADIOGRAPHY (NDT), LTD.
Gamma-ray scanning.
ISOTOPE DEVELOPMENTS, LTD.
MERVYN INSTRUMENTS.
MULLARD, LTD.
Photomultipliers, image converters.
NUCLEAR ENTERPRISES (G.B.), LTD.
Shielded units, multi-channel spectrometer.
PANAX EQUIPMENT, LTD.
RESEARCH AND CONTROL INSTRUMENTS, LTD.
Probes, photomultipliers.
SETON CREAGHE ENGINEERING CO., LTD.
20TH CENTURY ELECTRONICS, LTD.
Photomultiplier tubes.

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Oil; O rings.
BAKER, P. W., AND SONS (SALES), LTD.
Packless, shaft.
BEAKBANE, HENRY, (FORTOX), LTD.
Standard, oil-free, self-lubricating.
BURY FELT MANUFACTURING CO., LTD., THE.
Felt.
CHILLCOTTS, LTD.
Gaskets, washers, silicone, synthetic rubbers.
CRANE PACKING, LTD.
Shaft; corrosion resistant mechanical.
DOWTY SEALS, LTD.
O, square section rings; flange, bonded.
FAIREY AVIATION CO., LTD., THE.
FIRTH, THOS, AND JOHN BROWN, LTD.
Hydrogen seal rings.
FLEXIBOX, LTD.
Mechanical, all types rotary shafts.
HALL AND HALL, LTD.
Rubber.
JOBLING, JAMES A., AND CO., LTD.
Hermetic glass/metal.
KNITMESH, LTD.
High temperature.
LUCAS, JOSEPH, LTD.
Shaft.
MERCER, THOMAS, LTD.
"Mercer-Nilos" grease rings.
METRO-FLEX ATOMIC ENGINEERING, LTD.
Gas tight equipment, perimeter all-metal.
NAPIER, D., AND SON, LTD.
Shaft.
N.G.N. ELECTRICAL, LTD.
"Nygon" sheets, sealing rings.
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Graphite.
PALATINE TOOL AND ENGINEERING CO. (SURBITON), LTD.
Bellows.
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Shaft, synthetic rubber.
SOUND INDUSTRIES.
Mould rubber.
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TEDDINGTON INDUSTRIAL EQUIPMENT, LTD.
Static, rotary.
UNIVERSAL METALLIC PACKING CO., LTD., THE.
Rotary, high speed, pressure.
WESTON, CHARLES, AND CO., LTD.
Leather, rubber, splitshaft, O rings, mechanical.

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ANDEC, LTD.
BROWN, S. G., LTD.
Motors.
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Motors, tachogenerators.
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Pneumatic process, remote.
ERICSSON TELEPHONES, LTD.
Systems, amplifiers.
FAIREY AVIATION CO., LTD., THE.
Hydraulic, pneumatic.
GLOSTER AIRCRAFT CO., LTD.
HARVEY ELECTRONICS, LTD.
Special electro-mechanical devices.
INTEGRA, LEEDS AND NORTHRUP, LTD.
JONES, WALTER, AND CO. (ENGINEERS), LTD.
Motors.
KETAY, LTD.
Systems, tachometers, pick-offs, pressure ratio computers.
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Synchros, servomotors, servo amplifiers, magslips.
NEWTON BROS. (DERBY), LTD.
Motors.
PULLIN, R. B., AND CO., LTD.
Servo components.
SEALEY ENGINEERING CO., LTD.
Control systems.
SERVO UNITS, LTD.
D.C. amplifiers, gear boxes, E.M. devices.
SPERRY GYROSCOPE CO., LTD.
Synchros.
VACTRIC (CONTROL EQUIPMENT), LTD.
Motors.
SPERRY GYROSCOPE CO., LTD.
Motors.

## 229 SHIELDED CONTAINERS

ASHMORE, BENSON, PEASE AND CO.
Transport flasks.
ASSOCIATED LEAD MANUFACTURERS, LTD.
Lead containers; transport, storage.
BRUNTON AND CO., LTD.
Lead vessels.
DISTINGTON ENGINEERING CO., LTD.
Transit coffins, flasks.
ENTHOVEN SOLDERS, LTD.
Head containers, tubes.
FAIREY AVIATION CO., LTD., THE.
FOWLER, H. G., AND CO., LTD.
Lead.
GRAVINER MANUFACTURING CO., LTD.
GRAZEBROOK, M. AND W., LTD.
Lead.
HALL ENGINEERING, LTD.
Transport, storage coffins, trolleys, special.
HEAD WRIGHTSON PROCESSES, LTD.
Shielded cells.
HORSON, H. M., LTD.
Storage safes.
MOORES (BOURNEMOUTH), LTD.
Storage magazines, lead coffins.
NUCLEAR RESEARCH APPLICATIONS, LTD.
OPENSHAW, WILLIAM, LTD.
Lead shielded containers.
SAVAGE AND PARSONS, LTD.
Lead.
SCOTTORN, LTD.
Special vehicles.

## 230 SHIELDING BLOCKS

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Iron blocks.
ASSOCIATED LEAD MANUFACTURERS, LTD.
Lead blocks.
CHANCE-PILKINGTON OPTICAL WORKS.
Lead-glass blocks to 6.1 g/cc.
FLEETLANDS, LTD.
Windows.
FOWLER, H. G., AND CO., LTD.
Lead bricks; filling.
GENERAL RADIOLOGICAL, LTD.
Lead walling (A).
GRAVINER MANUFACTURING CO., LTD.
Lead blocks.
GRAZEBROOK, M. AND W., LTD.
Lead blocks, castles, containers.
GREY AND MARTEN, LTD.
Interlocking lead bricks.
HALL ENGINEERING, LTD.
Blocks, doors.
HULL, F., AND SONS, LTD.
Iron, lead.
INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.
Iron blocks.
REDIWELD, LTD.
Polyethylene.
UNIBRIX RADIATION SHIELDINGS, LTD.
"Unibrix" high density portable.

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Zinc bromide solution.
CAIRNES, JOHN M, AND CO., LTD.
Barytes aggregate.
DUNDEE CONTRACTING CO., LTD.
Whinstone aggregate.
ESKETT LIMESTONE QUARRIES, LTD., THE.
Heavy aggregate.
GENERAL ELECTRIC CO., LTD.
Heavy alloys.
HADFIELDS, LTD.
Steel plates.
HAM RIVER GRIT CO., LTD., THE.
Aggregates.
MALLINSON, WILLIAM, AND SONS, LTD.
Hydrobord (neutron), "Armourply" lead cored panels.
PETERS AND BARHAM, LTD.
Concrete aggregates.
UNITED CHEMICALS (LONDON), LTD.
Heavy aggregates, barytes, ilmenite.

## 232 SILICONES

ANGUS, GEORGE, AND CO., LTD.
Fluorocarbon plastics mouldings.
BITULAC, LTD.
"Bitulac," waterproofing.
IMPERIAL CHEMICAL INDUSTRIES, LTD.
Rubbers, resins, fluids.
MIDLAND SILICONES, LTD.
Fluids, greases, insulating varnishes, resins, rubbers.
SOUND INDUSTRIES.
Connectors, seals.
SYMONS, H. D., AND CO., LTD.
Elastomer products.

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BRITISH ELECTRICAL REPAIRS, LTD.
IGRANIC ELECTRIC CO., LTD.
MAGNETIC DEVICES, LTD.
N.S.F., LTD.
PELL, OLIVER, CONTROL, LTD.
PHILLIPS CONTROL (G.B.), LTD.

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ANDERTON SPRINGS, LTD.
Circlips, retaining pressings.
BEARDSHAW, J., AND SON, LTD.
Steels, all types.
BROADBENT AND CO. (ROCHDALE), LTD.
Precision, all metal; flat; hand-made.
CARY, WILLIAM E., LTD.
Laminated coil.
COCKBURNS, LTD.
Spiral.
DEVON INSTRUMENTS, LTD.
Instrument.

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Coil, flat metal.
**INTERNATIONAL ENGINEERING CONCESSIONAIRES, LTD.**
Disc, washers.
**RILEY, ROBERT, LTD.**
Compression, tension, torsion, extension, vehicle.
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Steel coil.

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Diesel driven, 75 to 730 kW.
**BLACKSTONE AND CO., LTD.**
Sets.
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Sets; auxiliary diesel engines.
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Gas, oil engines to 3,500 b.h.p.
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Sets; diesel engines.
**LISTER, R. A., AND CO., LTD.**
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**MIRRLEES WATSON CO., LTD., THE.**
Diesel plant.
**PERKINS, F., LTD.**
Diesel engines.
**PETBOW, LTD.**
Equipment, diesel plant.
**PETTERS, LTD.**
Equipment, diesel engines to 104 b.h.p.
**ROLLS-ROYCE, LTD.**
Equipment, diesel engines to 600 b.h.p.

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**ADAMSON, DANIEL, AND CO., LTD.**
Turbines.
**AITON AND CO., LTD.**
Evaporators, distillers.
**BALFOUR, HENRY, AND CO., LTD.**
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Electrode steam (medium, high voltage) boilers.
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Steam, hot water boilers.
**BRITISH BOILER ACCESSORIES, LTD.**
Accumulators.
**BROTHERHOOD, PETER, LTD.**
Turbines.
**BROWN, JOHN, AND CO., LTD.**
Turbines.
**CALOMAX (ENGINEERS), LTD.**
Water; steam operated, boilers.
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Auxiliary, steam, hot water, boilers.
**COPES REGULATORS, LTD.**
Feed water regulators, pump governors.
**CRADLEY BOILER CO., LTD.**
Boilers.
**DAVEY, PAXMAN AND CO., LTD.**
Shell, water tube, waste heat boilers.
**FOSTER YATES AND THOM, LTD.**
**GILBERT GILKES AND GORDON, LTD.**
Turbines.
**HICK HARGREAVES AND CO., LTD.**
Complete condensing plant, auxiliaries, evaporators.
**HYGROTHERM ENGINEERING, LTD.**
Dowtherm heat transfer systems, heat generators.
**INTERNATIONAL COMBUSTION (NUCLEAR APPLICATIONS), LTD.**
Separators, boilers.
**KAY, FREDK., (ENGINEERING), LTD.**
Fully automatic, gas, oil-fired boilers.
**LANCASTER AND TONGE, LTD.**
Traps, separators.
**MAXIM SILENCERS, LTD.**
Evaporating, distilling; blow-offs, silencers.
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Steam traps.
**MIRRLEES WATSON CO., LTD.**
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**PRIOR STOKERS, LTD.**
Underfeed stokers, oil burners.
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Scrubber elements.
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Turbines; distillation; feed-heating; condensing.
**SERCK RADIATORS, LTD.**
Condensers.
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Steam-raising equipment.
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Accumulators; heat recovery.
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Steam generators.
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**VICKERS-ARMSTRONGS (ENGINEERS), LTD.**
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Oil fired boilers.
**WIDNES WELDING CO.**
Condensers.
**WORTHINGTON-SIMPSON, LTD.**
Feed heating, air ejectors.

## 237 STEEL

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M.s., low-alloy; plates, sections.
**BAIRDS AND SCOTTISH STEEL, LTD.**
Bar, iron.
**BEARDMORE, WILLIAM, AND CO., LTD.**
Heavy plates.
**BEARDSHAW, J., AND SON, LTD.**
High speed, alloy, carbon, tool.
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**CONSETT IRON CO., LTD.**
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**DUNKERLEY, C. C., AND CO., LTD.**
S.s., alloy, tool; structural shapes.
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Strip, "Fircleve," flattened wire.
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Nitralloy; "Vane" for blower castings.
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S.s., heat, creep-resisting.
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Bars, rods, concrete reinforcements.
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Bright, drawn, bars, wire; heat treatment.
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Heavy plates; agents for S.I.A.C.
**HADFIELDS, LTD.**
Boron; low cobalt.
**INDUSTRIAL SPECIALITY (IRON AND STEEL), LTD.**
Reinforcing bars, sections, plates, sheets.
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Constructional, s.s., boron, special tool.
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Tool, stainless iron, high carbon, s.s.
**KINGSWAY TRADING CO., LTD.**
S.s.
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**LEE, ARTHUR, AND SONS, LTD.**
Carbon, alloy; "Trubrite" strip.
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Hardened, tempered, cold rolled strip.
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Tool, alloy, s.s. ingot, billet, bar.
**LOW MOOR FINE STEELS, LTD.**
Extruded solid, hollow sections all types.
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Stockholders.
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Alloy, s.s.
**PARK GATE IRON AND STEEL CO., LTD.**
M.s., carbon, alloy; bars, billets.
**REDHEUGH IRON AND STEEL CO. (1936), LTD.**
Rollers, m.s., alloy, special steels.
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Bright, drawn bars.
**SAVILLE, J. J., AND CO., LTD.**
Constructional, s.s., boron, tool, special.
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Heat, corrosion resisting.
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Joists, rail sections, pig iron.
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Customer specification.
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Plates, joists, sections, beams, rails, piling.
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Slabs, plates, sheets.
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"Remko" Swedish soft iron.
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Alloy, s.s., high temperature, vacuum melted.
**WORKINGTON IRON AND STEEL CO.**
Low residual, ingots, billets, slabs, bars.

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Medium, light.
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**STEAM AND COMBUSTION ENGINEERING, LTD.**
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**WEST'S GAS IMPROVEMENT CO., LTD.**
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Engineers.

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SITE INVESTIGATIONS CO., LTD.
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ARMSTRONG, SIR W. G., WHITWORTH AIRCRAFT, LTD.
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ARROW ELECTRIC SWITCHES, LTD.
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Flow, level.
BLACK AUTOMATIC CONTROLS, LTD.
Pressure, flow.
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Push button, rotary.
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Starter, pressure.
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Electronic, solonoid, thermal, time.
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Contactor starters to 300 h.p.
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Centrifugal.
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S.s., flow controlled.
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"Oak"; push; "Palec"; "Cutler-Hammer"; "Union."
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Remote control.
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Circuit breakers; isolating, instrument.
TECHNOGRAPH ELECTRONIC PRODUCTS, LTD.
Flush bonded high-speed.
TELEPHONE MANUFACTURING CO., LTD.
Relays.
THERMAL CONTROL CO., LTD.
Pressure operated.
TOK ELECTRICAL AND INDUSTRIAL MECHANISMS, LTD.
Rotary.
VACTRIC (CONTROL EQUIPMENT), LTD.
Rotary sampling.

## 242 SWITCHGEAR; Fusegear

A.E.W., LTD.
BELMOS CO., LTD., THE.
Motor control.
BRAY, E. N., LTD.
Contactors, motor control, relays, time delay.
BRITISH ELECTRICAL REPAIRS, LTD.
Tap change to 10,000 amp.
BRITISH INSULATED CALLENDER'S CABLES, LTD.
CHILTON ELECTRIC PRODUCTS, LTD.
Breakers, trips, cubicles, panels.
CROMPTON PARKINSON, LTD.
To 66 kV.
DORMAN AND SMITH, LTD.
Miniature circuit breakers.
GEIPEL, WILLIAM, LTD.
Contactors, control gear.
HEAT TRANSFER, LTD.
JOHNSON AND PHILLIPS, LTD.
LANCASHIRE DYNAMO NEVELIN, LTD.
LINE EQUIPMENT, LTD.
Switches to 400 kV.
M. AND C. SWITCHGEAR, LTD.
Circuit breakers to 1,600 amp.
MCGEOCH, WILLIAM, AND CO., LTD.
Switchboards, control desks, junction boxes.
MIDLAND ELECTRIC MANUFACTURING CO., LTD.
Motor panels, cubicles.
M.T.E. CONTROL GEAR, LTD.
Panels, contactors, relays, switches.
NELSON, W. AND H., LTD.
Fuse, circuit breaker panels, switchboards.
OTTERMILL SWITCHGEAR, LTD.
Switchboards, busbars, trunking.
PETBOW, LTD.
Control panels.
SOUTH WALES SWITCHGEAR, LTD.
To 33 kV, 1,000 MVA switchfusegear.
STATTER, J. G., AND CO., LTD.
To 15 kV, 350 MVA; breakers, transformers.
SWITCHGEAR ACCESSORIES, LTD.
To requirements, contacts all types.
THOMS, BERTRAM, (ENGINEERS), LTD.
Heavy.
VARILECTRIC, LTD.
Cubicles, panels, busbars, trunking, ducting.
WHIPP AND BOURNE, LTD.
WILCOX, EDWARD, AND CO., LTD.
Rewirable, H.R.C., inbuilt indicators.
YORKSHIRE SWITCHGEAR AND ENGINEERING CO., LTD.
Control, relay boards, circuit, breakers.

# T

## 243 THERMOCOUPLES

BAILEY METERS AND CONTROLS, LTD.
BAYLEY, F. S. CLANAHAN AND CO., LTD.
Wires; ceramic insulation.
BRUNTONS (MUSSELBURGH), LTD.
Composite lifting cable assemblies.
CROYDON PRECISION INSTRUMENT CO.
Potentiometers, switches.
DAY, J., AND CO. (DERBY WORKS), LTD.
Cables, slewings.
ENGELHARD INDUSTRIES, LTD.
High temperature.
HONEYWELL CONTROLS, LTD.
INDUSTRIAL PYROMETER CO., LTD., THE.
Indicating, controlling, recording.
INTEGRA, LEEDS AND NORTHRUP, LTD.
JOHNSON, MATTHEY AND CO., LTD.
LAND PYROMETERS, LTD.
Wires, heads, insulators, compensating cable.
PARMEKO, LTD.
Magnetic amplifiers.
PYE, W. G., AND CO., LTD.
Test set.
PYROTENAX, LTD.
Pyrotenax-mineral insulated.
RESEARCH AND CONTROL INSTRUMENTS, LTD.
Wire; miniature.
SPEMBLY, LTD.
Precision; thermopiles; thermal analysis.
TECHNOGRAPH ELECTRONIC PRODUCTS, LTD.
VACUUM INDUSTRIAL APPLICATIONS, LTD.
Gauges.

## 244 THORIUM

RIO TINTO GROUP, THE.
Oxide, sulphate, crude cake.
THORIUM, LTD.
Reactor grade oxide.

## 245 TOOLS

ABINGDON KING DICK, LTD.
ACRU ELECTRIC TOOL MFG. CO., LTD., THE.
Surface tables, plates.
ANGLO ABRASIVE WORKS, LTD.
Abrasives.
ARMSTRONG PATENTS CO., LTD.
Helicoil inserts.
ATLAS COPCO (GREAT BRITAIN), LTD.
Pneumatic.
BOWERS, T., AND CO.
BROOKE TOOL MFG. CO., LTD., THE.
Special cutters, nuclear graphite.
BROOM AND WADE, LTD.
Pneumatic.
B.S.A. TOOLS, LTD.
Small; machine shop equipment.
CARRINGTON, TOM., AND CO., LTD.
Taps, dies, screwing machines.
CONSOLIDATED PNEUMATIC TOOL CO., LTD.
Range pneumatic; metal working; grinders.
CORNERCROFT, LTD.
Jigs.
CUCKSON, W. E., AND SON, LTD.
Moulds, jigs.
DZUS FASTENER EUROPE, LTD.
Fasteners.
FIRTH BROWN TOOLS, LTD.
Drills, reamers, saws.
GAYDON, H. A., AND CO., LTD.
GLOBE PNEUMATIC ENG. CO., LTD.
Pneumatic.
HOLMAN BROS., LTD.
Pneumatic.
H.S.S., LTD.
Stockholders.
HUNTON, LTD.
INGERSOLL-RAND CO., LTD.
Air.
MACDONALD, JOHN, AND CO. (PNEUMATIC TOOLS), LTD.
"Macdonald" pneumatic.
MARSH BROS. AND CO., LTD.
"Camlock."
MERCER, THOMAS, LTD.
Gauges, all types.
MOLLART ENGINEERING CO., LTD., THE.
Comparators; gauges.
MONKS AND CRANE, LTD.
MOSS AND GAMBLE BROS., LTD.
Metalworking.
NEILL, JAMES, AND CO. (SHEFFIELD), LTD.
Hand, precision.
NETTLEFOLD AND MOSER, LTD.
Agent.
OSBORN, SAMUEL AND CO., LTD.
Engineers' cutting.
PIPEWORK AND ENGINEERING (BRISTOL), LTD.
Jigs, fixtures.
PITTER GAUGE AND TOOL CO., LTD.
Gauges, jigs.
PUREFOY, J. B., UNIT TOOLING, LTD.
Jig parts.
RAWLPLUG CO., LTD., THE.
Tools, fixing devices.
ROSSELL, HENRY, AND CO., LTD.
RUBERT AND CO., LTD.
Surface plates, gauges.
SHEFFIELD TWIST DRILL AND STEEL CO., LTD., THE.
STUBS, PETER, LTD.
Files.
TALBOT TOOL CO., LTD.
Layout fluid.
VACTRIC (PRECISION TOOLS), LTD.
Gauges, jigs.
VERALOY PRODUCTS, LTD.
WILLIAMS, H., AND SON, LTD.
WOLF ELECTRIC TOOLS, LTD.
Portable electric.

## 246 TUBES, EXTENDED SURFACE

ACCLES AND POLLOCK, LTD.
Precision, common, rare metals.
ADAMSON, DANIEL, AND CO., LTD.
Longitudinally finned.
BIRWELCO, LTD.
CLARKE, CHAPMAN AND CO., LTD.
CLAYTON DEWANDRE, CO., LTD.
CRITTALL-LUXFER, LTD.
Heat exchanger; non-ferrous metals.
FAIREY AVIATION CO., LTD., THE.
HEAT TRANSFER, LTD.
HOWELL AND CO., LTD.
HUNT AND MOSCROP, LTD.
Gilled.
IMPERIAL CHEMICAL INDUSTRIES, LTD.
"Integron"; non-ferrous.
LUCAS, JOSEPH, LTD.
Ferrous.
RICHARDS AND ROSS, LTD.
SIMON-CARVES, LTD.
SPIRO-GILLS, LTD.
THERMO ENGINEERS, LTD.
Gilled air heater, coolers.

## 246 TUBES, EXTENDED SURFACE (contd.)

T.I. NUCLEAR ENGINEERING, LTD.
TOMLINSONS (ROCHDALE), LTD.
"Turblek" gilled.
TUBE PRODUCTS, LTD.
Resistance welded.
TUBES, LTD.
UNITED AIR COIL, LTD.

## 247 TUBES, FLEXIBLE

ABBOFLEX, LTD.
Metallic, plastics, synthetic rubber.
AVICA EQUIPMENT, LTD.
S.s.
BOWDEN (ENGINEERS), LTD.
Medium, high pressure hose assemblies.
COMPOFLEX CO., LTD.
High temperature, pressure; liquid gas hoses.
EXTRUDEX, LTD.
Unplasticised PVC, polythene; to 15 in. bore.
JOHNSON AND PHILLIPS, LTD.
"Junotube," cabled, nylon, copper.
OIL FEED ENGINEERING CO., LTD.
Hi-flex PTFE.
PLASTICABLE, LTD.
Metallic.
POWER AUXILIARIES, LTD.
Seamless metallic hose; multi-bore.
POWER FLEXIBLE TUBING CO., LTD., THE.
Metallic.
SMITHS INDUSTRIAL INSTRUMENT DIVISION.
"Petro-flex."
TECALEMIT, LTD.
"Titeflex," metal; nylon.
UNITED FLEXIBLE METALLIC TUBING CO., LTD., THE.
Metallic.

## 248 TUBING

ACCLES AND POLLOCK, LTD.
Seamless, welded, drawn; precision.
ALMIN, LTD.
Aluminium.
BIRMINGHAM BATTERY AND METAL CO., LTD., THE.
Copper, alloy.
B.K.L. ALLOYS, LTD.
Carbon, alloy, s.s.; fittings.
BOOTH, JAMES, AND CO., LTD.
Non-ferrous.
BROWN, JOHN, AND CO., LTD.
Manipulation.
CHESTERFIELD TUBE CO., LTD., THE.
Seamless carbon, alloy, s.s., Be, Ti, Zr.
CLARKE, CHAPMAN AND CO., LTD.
Manipulation.
ELLAY TUBES, LTD.
Non-ferrous, aluminium, copper.
ENGELHARD INDUSTRIES, LTD.
Precious metal clad.
HEAT TRANSFER, LTD.
Ferrous, non-ferrous.
HOWELL AND CO., LTD.
Seamless, carbon, low alloy steels.
INDUSTRIAL SPECIALTY (IRON AND STEEL), LTD.
Steel.
KIRK AND CO. (TUBES), LTD.
Fittings, flanges, steel, s.s., iron, m.i.
LAMSON ENGINEERING CO., LTD.
Isotope carrier airtubes.
OSBORN, SAMUEL, AND CO., LTD.
Expanders.
PLASTICABLE, LTD.
Sheathed copper.
REYNOLDS TUBE COMPANY, LTD.
Cold drawn seamless steel.
RICHARDS AND ROSS, LTD.
B.F.E.D. tubing.
SERCK RADIATORS, LTD.
Condenser, heat exchanger.
TALBOT STEAD TUBE CO., LTD.
Carbon, alloy steel, s.s.; clad, graphite.
T.I. NUCLEAR ENGINEERING, LTD.
M.s., s.s., alloy steels.
TUBES, LTD.
Seamless steel to 8½ in. o.d.
UNITED AIR COIL, LTD.
Non-ferrous.
VICKERS NUCLEAR ENGINEERING, LTD.
Manipulation.
WELDLESS STEEL TUBE CO., LTD.
"Hot finished" seamless; carbon, alloy steels.
WELLINGTON TUBE WORKS, LTD.
Steel.
YORKSHIRE IMPERIAL METALS, LTD.
Steel, non-ferrous; fittings.

# U

## 249 URANIUM

ALBRIGHT AND WILSON (MFG.), LTD.
Tributyl phosphate.
ATOMIC ENERGY AUTHORITY.
FAIREY AVIATION CO., LTD., THE.
Machining.
PERMUTIT CO., LTD., THE.
Ion exchange plant.
RIO TINTO GROUP, THE.
Mill grade precipitate; nuclear grade salts; ceramic grade $UO_2$; metal machined ingot, forged, rolled, fabricated.

# V

## 250 VALVES

ALEXANDER CONTROLS, LTD.
Solenoid, servo, piston, air operated.
ALLEY AND MACLELLAN, LTD.
Steam, water, air, gas, oil.
APPLETON AND HOWARD, LTD.
For chemical corrosive liquids.
A.P.V. CO., LTD., THE.
S.s.
AUDLEY ENGINEERING CO., LTD.
"Audco" lubricated taper plug, "Annin" control.
BAILEY, SIR W. H., AND CO., LTD.
Sluice.
B.E.N. PATENTS, LTD.
Non-return, pressure reducing, relief, safety.
BENTON AND STONE, LTD.
Pneumatic.
BIRKETT, T. M., BILLINGTON AND NEWTON, LTD.
Fittings; cast rods, tubes.
BLACK AUTOMATIC CONTROLS, LTD.
Solenoid, diaphragm, pressure regulating, sampling.
BLAKEBOROUGH, J., AND SONS, LTD.
Gate: butterfly; globe; plunger; hinged door.
BLOCTUBE CONTROLS, LTD.
Precision, remote control.
BLUNDELL AND CROMPTON, LTD.
"Atmos" combined pressure, vacuum; relief.
BOVING AND CO., LTD.
Drop-tight butterfly, gas; sluice gates.
BRADSHAW AND CO. (ACCRINGTON), LTD.
Motorized standard, specials.
BRITISH ARCA REGULATORS, LTD.
Diaphragm operated control.
BRITISH ERMETO CORPORATION, LTD.
H.p. shut-off, control, non-return, bellows.
BRITISH STEAM SPECIALITIES, LTD.
"Velan" bellows seal, forged s.s. (A).
C.A.V., LTD.
Electro-pneumatic.
CHAMBERLAIN INDUSTRIES, LTD.
Hydraulic.
COCKBURN'S, LTD.
Fluid, gas, vapour; cast, fabricated; controls.
CORTIN AND CORKING, LTD.
Acid (Regulus metal).
CROSBY VALVE AND ENGINEERING CO., LTD.
Safety, relief, diaphragm operated.
DANFOSS MANUFACTURING CO.
Manual shut-off.
DE HAVILLAND ENGINE CO., LTD., THE.
Small for radioactive circuits.
DEWRANCE AND CO., LTD.
Steam feed, gas, safety, relief.
DONKIN, BRYAN, CO., LTD., THE.
High pressure gas.
DOWTY NUCLEONICS, LTD.
Rotary selector; manual, pneumatic, solenoid operated.
DRAYTON REGULATORS AND INSTRUMENT CO., LTD.
Control to 2,500 p.s.i., 1,100°F.
EDWARDS HIGH VACUUM, LTD.
Vacuum; protective devices.
ELECTRO-HYDRAULICS, LTD.
Hydraulic, pneumatic, solenoid; vacuum, reducing, relief.
ELLIOTT NUCLEONICS, LTD.
Control.
ETHER, LTD.
Magnetic, solenoid.
FARRER, WILLIAM E., LTD.
Steel, c.i.; sluice gates, penstocks.
FARRIS ENGINEERING, LTD.
Safety, relief; steel, s.s., bronze, rubber.
FIRKINS, G. AND A., LTD.
Hydraulic, air operated, motorized.
FIRTH, THOS., AND JOHN BROWN, LTD.
Runaway stop, governor.
FISHER GOVERNOR CO., LTD.
Pneumatic, electronic-operated, control, butterfly, specials.
FLEISCHMANN (LONDON), LTD.
High vacuum.
FLEXIBOND, LTD.
Stop.
GENEVAC, LTD.
Vacuum, baffle, ancillary equipment.
GLENFIELD AND KENNEDY, LTD.
Sluices; reactor coolant systems; consultation, design.
GOODWIN, ARNOLD, LTD.
Air, hydraulic control.
GORDON, JAMES, AND CO., LTD.
Control, shut-off.
HAM, BAKER AND CO., LTD.
Water, penstocks, sluice valves.
HAMWORTHY ENGINEERING, LTD.
HARLAND ENGINEERING CO., LTD., THE.
"Rotovalves."
HIGH-PRESSURE COMPONENTS, LTD.
IGRANIC ELECTRIC CO., LTD.
INNESS AND CO. (DARLINGTON), LTD.
Industrial.
INTEGRAL, LTD.
Hydraulic.
I.V. PRESSURE CONTROLLERS, LTD.
High temperature; magnetic, manual.
JONES AND STEVENS, LTD.
Solenoid, pressure, vacuum, taps.
KLINGER, RICHARD, LTD.
Automatic, cocks.
KSB MANUFACTURING CO., LTD.
Glandless.
LANGLEY ALLOYS, LTD.
S.s., nickel alloy.
LANG PNEUMATIC, LTD.
Solenoid.
LANGDALE ENGINEERING CO.
Regulating, solenoid sequence, hydraulic.
LONGCLOSE ENGINEERING CO., LTD.
Fullway.
LUCAS, JOSEPH, LTD.
Hydraulic, magnetic, pneumatic, reducing.
MACDONALD, JOHN, AND CO. (PNEUMATIC TOOLS), LTD.
Pressure-seated air.
MAGNETIC VALVE CO., LTD., THE.
Magnetically operated, automatic control, ancillaries.
MARTONAIR, LTD.
Control, pneumatic, hydraulic.
MERRILL PUMPS, LTD.
Pressure relief, corrosive fluids.
METRO-FLEX ATOMIC ENGINEERING, LTD.
Isolating duct.
MEYNELL AND SONS, LTD.
Gunmetal; steam, air, gas; fittings, specials.
MIDLAND INDUSTRIES, LTD.
Pressure reducing, stop, check.
MILLS PAUGH, LTD.
"DeZurik."
MOORES (BOURNEMOUTH), LTD.
High pressure, s.s.
MUNTZ, ALAN, AND CO., LTD.
Automatic, air.
NEWMAN, HENDER AND CO., LTD.
Bellows; gate, globe, needle, parallel slide.
N.G.N. ELECTRICAL, LTD.
Magnetic to 4 in. bore, hand, baffle.
NORGREN, C. A., LTD.
Compressed air, liquid pressure regulators, reducing.
NUMATION VALVES, LTD.
Electro-pneumatically operated pinch.
N.V. TOOLS, LTD.
S.s.; high, low pressure, relief.
PALATINE TOOL AND ENGINEERING CO. (SURBITON), LTD.

## 250 VALVES (contd.)

**PALMER AERO PRODUCTS, LTD.**
Hydraulic.
**PULVERIZING MACHINERY, LTD.**
Diaphragm, s.s., copper, m.s., glass lined.
**RESISTANT EQUIPMENT, LTD.**
**RHODES, B., AND SON, LTD.**
Cocks, pure nickel, s.s., monel.
**RICHMOND INSTRUMENT CO., LTD.**
High vacuum; special apparatus.
**ROTHERHAM AND SONS, LTD.**
Taps.
**RYDER, THOS., AND CO. (MANCHESTER), LTD.**
Cocks; s.s., g.m., c.i., aluminium.
**SAMSON CONTROLS (LONDON), LTD.**
Controllers (A).
**SANDFORD, THOMAS, (ROCHDALE), LTD.**
Water, steam.
**SAUNDERS VALVE CO., LTD.**
Diaphragm.
**SAUTER CONTROLS, LTD.**
Pneumatically, solenoid operated.
**SCOTTS ENGINEERING (NEWPORT), LTD.**
"Scotomic" diaphragm; liquids, gases, solenoid (A).
**SIMMONDS AEROCESSORIES, LTD.**
Liquid.
**SPRINGHAM, G., AND CO.**
High vacuum glass stopcocks.
**SMITH, SYDNEY, AND SONS (NOTTINGHAM), LTD.**
High pressure; cocks.
**TALBOT STEAD TUBE CO., LTD.**
"Cupford" diaphragm.
**TEDDINGTON INDUSTRIAL EQUIPMENT, LTD.**
Bellows sealed, solenoid, motorized, high vacuum.
**TELEKTRON (GREAT BRITAIN), LTD.**
Pneumatic, motorized position indication.
**TERRASPAN, LTD.**
Prototypes.
**TOWLER BROS. (PATENTS), LTD.**
Oil, hydraulic, control.
**URQUHARTS (1926), LTD.**
Multi-port, control.
**VACUUM INDUSTRIAL APPLICATIONS, LTD.**
Vacuum; leak, servo, controlled.
**VACUUM RESEARCH (CAMBRIDGE), LTD.**
Vacuum; hand, air-operated to 24 in.
**VICKERS NUCLEAR ENGINEERING, LTD.**
**V.M.D., LTD.**
Vacuum pressure; 1 in. to 48 in.
**WALKER, C. AND W., LTD.**
Solenoid; gas.
**WARREN, MORRISON, LTD.**
Rubber diaphragm, pinch.
**WESTERN DETAIL MANUFACTURERS, LTD.**
Vacuum.
**WILKINSON RUBBER LINATEX, LTD.**
**WILLIAMS AND JAMES (ENGINEERS), LTD.**
Reducing, bronze, s.s.

# W

## 251 WATER TREATMENT
*see also DEMINERALIZATION PLANT, EFFLUENT TREATMENT*

**BRACKETT, F. W., AND CO., LTD.**
Self-cleaning screens, strainers.
**CANDY FILTER CO., LTD., THE.**
**FARRER, WILLIAM E., LTD.**
Screens, sludge removal, sewage purification.
**HEAT TRANSFER, LTD.**
**HICK HARGREAVES AND CO., LTD.**
Self cleaning strainers, de-aerators.
**HOUSEMAN AND THOMPSON, LTD.**
Equipment, service.
**LANCASTER AND TONGE, LTD.**
Strainers; single, duplex to 24 in. bore.
**LEDWARD AND BECKETT, LTD.**
Spray cooling nozzles.
**PERMUTIT COMPANY, LTD., THE.**
**PULSOMETER ENGINEERING CO., LTD., THE.**
**SIMON-CARVES, LTD.**
Purification plant.
**STEEL, J. M., AND CO., LTD.**
Hydrazine cpds., "Lewatit" ion exchange resins.
**THOMPSON, JOHN, LTD.**
**THOMPSON-KENNICOTT, JOHN, LTD.**
Softeners, deaerators.
**WALLACE AND TIERNAN, LTD.**
Chlorination plant.
**WESTWOOD, JOSEPH, AND CO., LTD.**
Screens.
**WHIFFEN AND SONS, LTD.**
"Zerox" hydrazine, "Metaquest," "Ralsin" (A).

## 252 WELDING

**A.I. ELECTRIC WELDING MACHINES, LTD**
Automatic flash butt.
**ALUMINIUM WIRE AND CABLE CO., LTD.**
Aluminium metal, alloy wire.
**ARC MANUFACTURING CO., LTD.**
Transformers, rectifiers, argon arc accessories.
**BADDELEY, D. S., ENG. CO., LTD.**
Acetylene, electric arc, resistance equipment.
**BRITISH INDUSTRIAL GASES, LTD.**
Equipment, accessories, cutting, heating.
**BRITISH INSULATED CALLENDER'S CABLES, LTD.**
**BRITISH OXYGEN GASES, LTD.**
Argonarc, "Lynx," semi-automatic, gas shielded.
**BROWN, JOHN, AND CO., LTD.**
Electrodes, equipment.
**COOPER AND TURNER, LTD.**
Electrodes.
**COURTBURN POSITIONERS, LTD.**
Positioners, cylinder rotators; "Interlas" accessories, (A).
**DELORO STELLITE, LTD.**
"Stellite" rods.
**ELECTRO MECHAN-HEAT, LTD.**
Spot, stitch, seam, special purpose equipment.
**EUTECTIC WELDING ALLOYS CO., LTD.**
Eutectics, low temperature alloys.
**FARR, EDWARD, LTD.**
Automatic plant.
**IBBETT ENGINEERING CO., LTD.**
Positioners.
**INVICTA ELECTRODES, LTD.**
Metal arc welding electrodes.
**JOHNSON, MATTHEY AND CO., LTD.**
Electrodes.
**LINCOLN ELECTRIC CO., LTD.**
Automatic, semi-automatic submerged arc; electrodes, accessories.
**MERITUS (BARNET), LTD.**
Resistance welding machines.
**MINNESOTA MINING AND MANUFACTURING CO., LTD.**
"Scotch" glass cloth tape.
**MUNRO AND MILLER, LTD.**
Fittings.
**MUREX WELDING PROCESSES, LTD.**
Metal arc; automatic; open, submerged, ancillaries.
**NELSON ENGINEERING CO., LTD., THE.**
**NEWBURGH ENGINEERING CO., LTD.**
Automatic machines.
**OXHYCARBON CO., LTD.**
Oxy-acetylene equipment.
**PETBOW, LTD.**
Arc; plant, accessories.
**PETERS, G. D., AND CO., LTD.**
Electrodes, accessories.
**PHILIPS ELECTRICAL, LTD.**
Electrodes, arc, plant, $CO_2$ equipment.
**PIPEWORK AND ENGINEERING (BRISTOL), LTD.**
Argon, gas processes.
**QUASI-ARC, LTD.**
Manual, semi-, fully-automatic, installations; electrodes.
**RADIO HEATERS, LTD.**
Plastics.
**REDIFON, LTD.**
R.F. plastics; tongs.
**ROCKWELD, LTD.**
Automatic, manual arc.
**ROSS, DONALD, AND PARTNERS, LTD.**
Jigs, positioners, manipulators, rotators, pipe tools.
**SATURN INDUSTRIAL GASES, LTD.**
Saturn-Hivolt, surge, injector, argon, arc.
**SUFFOLK IRON FOUNDRY (1920), LTD.**
Rods, fluxes, equipment.
**WELDCRAFT, LTD.**
**WELDING SUPERVISION, LTD.**
Control, supervision of fabrications.
**WELDING SUPPLIES, LTD.**
Electrodes, generators, extractor fans.
**WESTERN DETAIL MANUFACTURERS, LTD.**
Argon purification plant.
**YATES PLANT, LTD.**
Complete fully automatic installations.
**YOUNG, A. S., AND CO., LTD.**
Rods, electrodes, fluxes, accessories; arc.

## 253 WINDOWS
*see also REMOTE HANDLING*

**BERK, F. W., & CO., LTD.**
Zinc bromide solution.
**CHANCE-PILKINGTON OPTICAL WORKS.**
To 4 ft 6 in. by 3 ft 6 in., 4.3 g/cc.
**EVANS, J., AND SON (PORTSMOUTH), LTD.**
Zinc bromide.
**FLEETLANDS, LTD.**
**MARINE AND INDUSTRIAL PLASTICS, LTD.**
**MENDIP (CHEMICAL ENGINEERING), LTD.**
Liquid filled.
**OPTICAL WORKS, LTD.**
Lead glass, liquid.
**UNIBRIX RADIATION SHIELDINGS, LTD.**
Lead glass.
**WESTERN DETAIL MANUFACTURERS, LTD.**
**WILSON, A. C., AND PARTNERS, LTD.**
Liquid filled.

## 254 WIRE; Wirework

**ALUMINIUM WIRE AND CABLE CO., LTD.**
"Andodal"; electrical purity, anodized.
**BARNS, W., AND SON (HOLLOWAY), LTD.**
Meshing, perforated metals, cable trays.
**BRITISH ROPES, LTD.**
Steel wire for prestressed concrete.
**CARTER, B. AND F., AND CO., LTD.**
Braiding, cable, rope machinery.
**CONNOLLYS (BLACKLEY), LTD.**
Insulated single; stranded, strip.
**G.K.N. REINFORCEMENTS, LTD.**
Steel for prestressed concrete.
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